AN ANALYSIS OF THE RELATIONSHIP BETWEEN ENVIRONMENTAL MANAGEMENT AND ENVIRONMENTAL COMPLIANCE AT MARINE CORPS INSTALLATIONS

THESIS

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Abstract

Environmental compliance on military is challenging for a number of reasons, including the complexity of regulations, and the variety of operations which impact the environment. At times, public concerns and penalties stemming from environmental issues has infringed upon the United States Marine Corps' (USMC) ability to use all installation resources without restriction. This thesis examines which facets of environmental management are closely associated with high levels of compliance. Five variables of interest: Total Compliance, Total Management, Audit Management, Policy Management, and Training Management were isolated from 1998-2004 USMC environmental audit data, and subjected to statistical analysis. Through the examination of four specific research questions, it was found that a) the Marine Corps has been meeting environmental compliance and management standards despite limited resources, b) in all areas, high Management scores were associated with high Total Compliance scores, c) the level of Management in all areas has improved over time, and d) difficulties with non compliance are most often associated with a lack of Resources.

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Bevin J. Keen

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I. Introduction

1.1 Background

United States Marine Corps (USMC) installations must comply with environmental laws and regulations, while ensuring access to resources needed to train and make Marines. Environmental compliance on a military installation is challenging for many reasons, including the complexity of environmental requirements, a culture where mission accomplishment is the first priority, and the constant turnover of personnel associated with rotations and deployments. Environmental professionals at USMC installations must therefore focus limited resources on activities that have the greatest potential to sustain environmental compliance and prevent occurrences of noncompliance.

In the face of increasing environmental regulations, both civilian and military organizations have been forced to give more thought on how their operations impact the environment on a daily basis. Initially, organizations dealt with environmental problems in a reactive fashion - as they occurred. Over time, and as penalties for noncompliance increased, organizations began to see that proactive management of environmental issues on a daily basis would be more effective in preventing environmental problems, as opposed to crisis management after the problems occurred.

This study assesses and analyzes both environmental management and environmental compliance through past USMC environmental audit data. These USMC environmental audits, formally known as Environmental Compliance Evaluations (ECEs) measure an installation's compliance and management posture by evaluating whether installation activities and operations are conducted in accordance with applicable Federal, state, local, and Department of Defense (DoD), and Marine Corps regulations. Marine Corps environmental management is focused in three key areas: Audit Management, Policy Management, and Training Management. By determining which environmental management facets are strongest when high compliance levels are present, environmental professionals at Marine Corps installations can better focus environmental management efforts to promote high levels of environmental compliance.

1.2 Summary of Current Knowledge

Attempts to smoothly integrate environmental management issues into existing management frameworks have proven difficult. To date, organizations have adopted a variety of techniques to manage environmental issues and attempt this integration. Although the environmental challenges that each organization faces are unique in some respects to the operations and structure of the individual organization, there are some common management issues which all organizations must address to remain within compliance with environmental regulations and standards. Furthermore, environmental goals and objectives may vary depending on an individual organization's larger strategy.

Technical Committee 207 of the International Standards Organization (ISO), met in the early 1990s to theorize what common elements should be included in an environmental management program (von Zharen, 1996). Based on a concept similar to the Quality Management (von Zharen, 1996) framework that is part of the ISO 9000 series standards, the ISO created a generic environmental management framework known as the Environmental Management System (EMS), published in 1995 as part of the ISO 14001 standard (Montabon et al, 2000). The ISO 14000 series are a family of process based standards intended to provide a generic management framework which promotes proactivity in environmental management. Such initiatives in the international community illustrate how organizations are attempting to improve environmental program quality through conscientious management. In the late 1990s, the United States government began to actively promote environmental management based on the ISO 14001's EMS framework. However, few practical studies have indicated which facets of environmental management are the most critical in attaining high levels of environmental compliance, and moreover to attain levels of environmental performance beyond the requirements of current compliance laws and regulations.

1.3 Problem Identification

In the past seven years, environmental professionals in the Marine Corps have tried different approaches to integrate environmental matters into the mainstream of installation operations. Environmental management policies have evolved from a more reactive compliance-based approach to those that take a more preventive and proactive approach. Environmental managers and professionals who work in a proactive mode may be able to efficiently improve the overall environmental performance at an installation. Environmental noncompliance can have negative consequences and may result in fines, civil lawsuits, negative publicity, or periodic limitation of land use which could hinder vital training operations. Effective management of compliance at Marine Corps installations includes steps to prevent and resolve compliance deficiencies by focusing on the most influential and relevant management factors and making appropriate investments to assure compliance. Effective management can also include steps to improve the existing environmental management structure to attain higher levels of environmental protection beyond what is required by applicable laws and regulations. It has not always been clear what environmental management functions may have the most influence on ensuring high levels of environmental compliance. This study isolates five variables of interest which measure the environmental posture of an installation from the past seven years (1998-2004) of USMC ECE data: Total Compliance, Total Management, Audit Management, Policy Management, and Training Management. The scores received in each area indicate the level of achievement in each area, and relationships between the areas can then be determined. Part of this study also examines the reasons behind non compliance, as indicated by root cause classifications, which are attributed to each compliance deficiency that is noted on an ECE. By identifying relationships between these key variables from ECE data, more can be learned about what types of environmental management work best to promote high levels of compliance.

1.4. Research Approach

The first step in this research endeavor is to conduct a literature search to define contemporary environmental concepts. First, what constitutes environmental compliance for an organization is clearly defined. Characteristics of overall environmental performance are distinguished from those of environmental compliance. Then a discussion linking an organization's strategy to its choice of environmental policy ensues. The spectrum of environmental management programs are examined, with specific reference to the ISO 14001 standards involving Environmental Management Systems (EMS). Initiatives within the Federal government, with particular focus on Department of Defense (DoD) and USMC policies in environmental management are addressed. The former information is provided predominantly through a literature search.

The Environmental compliance and environmental management data used in this research was obtained from previous USMC ECEs conducted at Marine Corps installations. This data was collected and supplied by Potomac Hudson Engineering, Inc (PHE), a government contractor that supports Headquarters, Marine Corps (HQMC) by conducting Environmental Compliance Evaluations (ECEs). The ECEs consist of a series of questions which measure the degree of environmental management as well as environmental compliance on individual Marine Corps installations. First the data was formatted for analysis, then the management and compliance variables of interest are isolated from other audit data. Then information was transformed from counts into decimal fractions, representing management and compliance scores for individual installations. The information is used to answer the research questions of this study through the use of descriptive and inferential statistics with the aid of JMP, version 5.1

(Allen, 2004), a statistical analysis software program. The analysis revealed the distribution of scores and evaluated hypotheses concerning the relationship between environmental management and environmental compliance over a seven year period of ECE results.

1.5 Research Questions

This research uses both management and compliance scores from Marine Corps environmental audits over the past seven years to determine how environmental management is related to environmental compliance. This is explained through the investigation of several investigative questions which are listed below:

1. How are the aggregate Total Management, Audit Management, Policy Management, Training Management, and Total Compliance scores distributed? Furthermore, how are the different types of management scores distributed when ordered by compliance standing?

2. What is the relationship between each management area (Total Management, Audit Management, Policy Management, Training Management) and Total Compliance?

3. How do Total Management, Audit Management, Policy Management, and Training Management scores compare between earlier (1998-2001) and later (2001-2004) series of evaluations?

4. How are the root causes of compliance deficiencies (i.e. Management, Plans & Procedures, Resources, or Training emphasis) grouped when ordered by their compliance standing and when ordered by the time period they occurred in?

1.6 Assumptions

1. This study assumes all ECE data collected by the environmental audit teams is accurate. This study also assumes that the environmental audit teams assessed each installation consistently through the course of all ECEs.

2. This study also assumes that all installations had adequate resources available in terms of funds and staffing, to meet compliance levels required by applicable laws and regulations.

1.7 Scope

This research has limited scope in several ways. First, the research does not take into account how fluctuating funding levels may have impacted management and compliance results in the ECEs. Decreased funding during certain periods of time might have decreased environmental activities and possibly the ability to comply. Also, while all negative evaluation responses are counted equally in terms of the management and compliance scores, the magnitude and severity of a noncompliant area may vary. Next, this study is focused on management and compliance data from Marine Corps installations. Therefore, results and conclusions are primarily applicable to the Marine Corps. Finally, because the data was collected from existing sources and not collected in the construct of a designed experiment, results are used to indicate the trends over time and relationships between environmental management and environmental compliance, but cannot be used to show causality between the two areas.

1.8 Summary

This study seeks to identify the critical environmental management facets which are present in conjunction with high levels of environmental compliance. By identifying these facets, the Marine Corps can manage environmental programs in an efficient and effective manner by focusing resources in management that will make a positive difference in compliance levels. The results of this study might also provide practical information to compare with existing standards, such as the ISO 14001 concept of EMS, which is based in theory, as to which management functions should be emphasized in a Marine Corps EMS.

II. Literature Review

2.1. Defining Contemporary Environmental Compliance

2.1.1. Determining the Environmental Requirements of an Organization.

During the 1970s and 1980s, the Federal government, under the guidance of the Environmental Protection Agency, passed hundreds of statutes and promulgated many complex environmental regulations with state and local governments following suit. These laws and regulations were passed to protect the natural environment and alleviate the effects of pollution on human health and the ecosystem (Friesen, 2003). While the 1970s and 1980s were the era of environmental regulation, the 1990s shaped up as the period of enforcement of these laws (Chilcutt 1995). Until the last decade, Federal facilities had sovereign immunity from enforcement, penalties, and certain governmental regulations concerning the environment. The Federal Facilities Compliance Act of 1992 was the first of several reauthorizations which effectively waived the sovereign immunity of Federal facilities, making them accountable to the same degree as private organizations (Office of Environmental Policy & Assistance, 1997; Hepler and Neumann, 2003).

As Federal facilities became subject to a vast array of environmental regulations, various branches of the Federal government, to include the Department of Defense (DoD) began to unify its efforts under common environmental policy. In turn, the individual services, to include the United States Marine Corps (USMC), under the Department of the Navy (DoN), also issued environmental policy directives, which addressed environmental issues that were service-specific. Therefore, the type of requirements that an organization is subject to primarily depend on its physical location, as that determines which state and local laws are applicable. If the organization is military in nature, then it will also be subject to DoD and service environmental policy. All organizations, public and private, are subject to the same Federal environmental regulations.

Environmental laws typically set maximum acceptable levels of emissions to the air, soil, and water as well as define acceptable protocols in the manufacture, transport, storage, and disposal of wastes (Chilcutt 1995). Federal regulations cover the air, water, land, solid waste, and hazardous waste media, and also address the management of forestry, fish, wildlife, and other environmental, natural, and cultural resources (DON, HQMC, 1998). Two well known laws which regulate emissions are the Clean Air Act and the Clean Water Act, which aim to preserve a certain environmental quality in an area. The Comprehensive Environmental Response, Compensation, and Liability Act as well as the Resource Conservation and Recovery Act are two laws which set strict requirements on the handling of wastes, and accountability for restoration after environmental damage has been done (Chilcutt, 1995). Each year, U.S. industry spends tens of billions of dollars on regulatory compliance and remediation of hazardous waste sites (Chilcutt, 1995). Regulations and enforcement of those regulations have driven most improvements that organizations have made in their environmental posture in the past 25 years (Office of Environmental Policy & Assistance, 1997).

While the level of environmental compliance can be determined by the degree to which an organization is meeting legal environmental requirements, the achievement of higher levels of environmental performance goes beyond compliance requirements. Improvements in environmental performance measure to what degree an organization is surpassing compliance requirements, or how the company has improved its relations between its activities and the environment (Young and Rikhardsson, 1996). A synthesis of the literature enabled the creation of a model to describe the spectrum of environmental performance, shown in Figure 1.

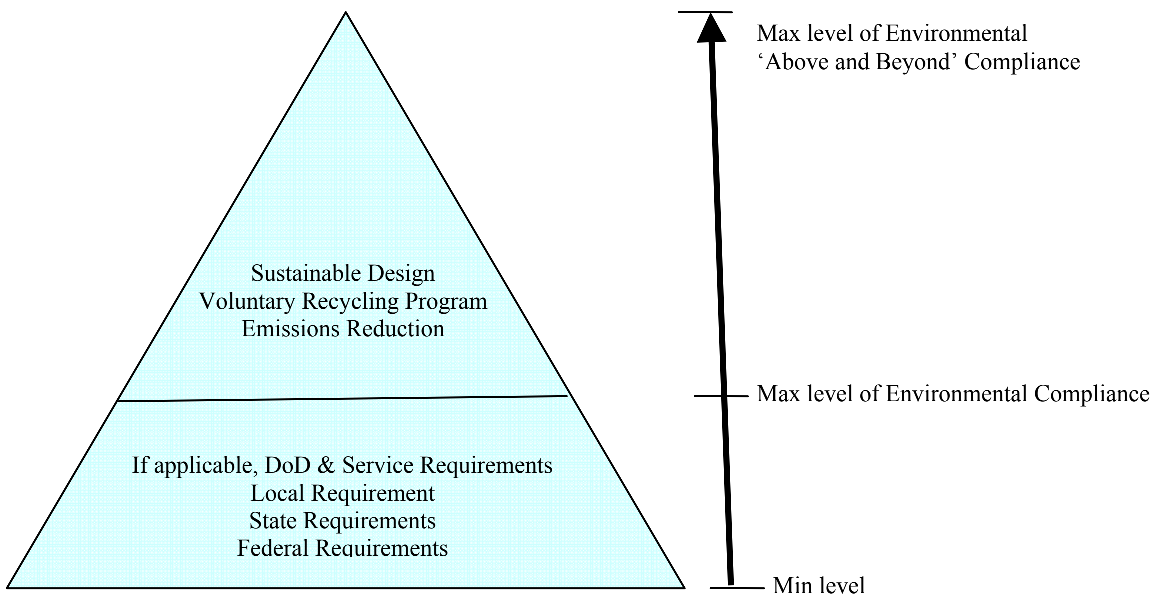


Figure 1: Environmental Performance Model. A model showing that environmental compliance to meet legal requirement is the first level of the pyramid, higher environmental performance levels can be reached by performing non voluntary steps to protect and preserve the environment.

As seen in Figure 1**,** environmental compliance forms the base of the pyramid. The environmental compliance posture of an organization is formed from the aggregate of all the applicable environmental regulations. In terms of these regulations, each regulation is discretely quantified, as the organization is either in compliance with a requirement or not in compliance with a requirement. The upper levels of the pyramid, representing higher levels of performance, can be attained by going 'above and beyond' the minimum legal environmental requirements that an organization is subject to. This includes nonmandatory efforts to increase efficiency and reduce pollutive emissions or waste. Clearly higher levels of performance can be attained when a firm focuses on the dramatic reduction of negative environmental impacts (Melnyk et al., 2003). One way to do this would be for the organization to reduce its environmental effects through lessening the physical changes the organization causes in the natural environment through its activities (Young and Rikhardsson, 1996).

2.1.2. Measuring and Assessing the Level of Compliance of an Organization.

A synthesis of current research indicated that there are two chief ways to assess the level of environmental compliance in an organization; through specific metrics or through environmental compliance audits. As environmental issues have had a growing impact on an organization's resources, managers have become increasingly interested in the measurement of compliance to gauge the environmental posture of their organization. Some internal processes suggested by James and Bennett (1996), for measurement and collection of environmental data include:

- Monitoring the organization's improvements over time
- Comparing the environmental posture to other benchmark organizations in the industry
- Incorporating environmental costs and benefits into business analyses
- Setting management priorities for action or improvement

James and Bennett (1996), also suggest that external drivers for measurement and collection of environmental compliance may include:

- Reporting requirements to enforcement/oversight agencies
- Demands from customers for information about environmental compliance
- Concerns of shareholders, lenders, and insurers that their financial interests are not threatened by poor environmental compliance

If organizations wish to respond to these internal and external requirements (James and Bennett, 1996; Pearson, 1999), they must examine what measures of environmental compliance can be used and how measures can be introduced. The ultimate aim of using environmental measures is to identify and reduce environmental impacts and further the organization's strategy (James and Bennett, 1996). Additionally, the value of metrics and audits relate directly to the number and nature of corporate decisions it influences (Richards, 1999).

There are numerous schools of thought and methods to structure a protocol for collecting metrics. A variety of measures may be used, and several researchers have conducted studies to assess the utility of environmental metrics. In the short term, metrics may concern efficiency, emissions, and wastes (James and Bennett, 1996). Common short term metrics which are frequently tracked could include energy efficiency and emission data on noxious chemicals, such as carbon dioxide and nitrogen dioxide (Ramsey, 2002). Mid-term and long term metrics might involve the measurement of processes and activities needed to assess a) their ultimate ecological impacts and b) the bottom line implications of corporate environmental policies (James and Bennett, 1996). How these metrics are attributed is also a debated issue. Young and Rikhardsson (1996) advocates separating the metrics according to four common company functions: processes, product, financial, and management. Particularly within the business world, there is great interest in being able to better quantify environmental performance through financial metrics, in order to better judge how and when money should be spent on environmental issues. However, it can be difficult to define which of an organization's costs are specifically related to the environment. Also, it may be difficult to track the benefit of expenditures over time, such as comparing the benefit of a short term 'end of the pipe' solution versus a longer term solution which targets pollution prevention in a more fundamental manner (James and Bennett, 1996).

Some organizations have dealt with mushrooming potential liabilities by systematically assessing their environmental compliance efforts through an audit process. The audit process results in an environmental compliance profile that shows whether the company satisfactorily complies with regulations and whether the potential for future noncompliance exists (Chilcutt, 1995). Audits are probably the most straightforward way to measure and assess the level of compliance as it compares an organization's status directly to well-defined requirements which are written in the form of laws and regulations. Audits may be divided into different categories depending on who performs the audit (internal or external) as well as the specific purpose of the audit (to evaluate environmental compliance or an environmental management program).

Internal audits are useful in determining the environmental posture of an organization, either of environmental compliance, environmental management, or both areas, for assessment purposes. When audits are performed by independent professional auditors, these documents are an excellent resource for the sponsoring organization. (Hepler and Neumann, 2003). External audits are often regulatory in nature and seek to assess the organization's compliance level and enforce environmental regulations in tandem. The regulator may use inspections to educate organizations about the regulations, and reductions in violations are possible even in the absence of punishment (Eckert, 2004). Various types of punishments may result if a regulatory agency, such as the EPA, discovers that an organization is in noncompliance with a given regulation during an audit. These disincentives include written reprimands known as Notice of Violation (NOV), formal cease and desist orders which can halt an organization's activities which are harming the environment, and also monetary fines which are higher, the more grievous the departure from acceptable compliant behavior. The threat of higher maximum fines has been shown to deter violations (Friesen, 2003). Frequent monitoring and relatively high fines have been effective in the past to deter firms from violating regulations (Friesen, 2003).

An environmental compliance audit is a methodical examination to determine whether an organization meets applicable legal, regulatory and other environmental requirements such as internal policies or standards (Wilson, 1999). Compliance audits involve a careful review of key documents, including air, water, or hazardous waste permits, emergency emission plans, and written and documented employee training programs. This type of audit verifies whether actual legal and regulatory requirements are being met. The compliance audit process not only results in an environmental profile that shows whether the company satisfactorily complies with regulations, but also whether the potential for future noncompliance exists (Chilcutt, 1995).

The principal differences between an EMS audit and an environmental compliance audit are the audit criteria: the policies, practices, procedures, or requirements against which the auditor compares audit evidence (Wilson, 1999). Hepler and Neumann (2003) note that compliance audits focus attention on noncompliance issues, and by correcting the deficiencies a facility can become more compliant. Regulatory based audits like this are good to police nonconforming facilities, but they do not seek the root causes of noncompliance. Audits of this type are not expected to achieve high levels of environmental performance. Identifying deficiencies is only the first step as real audit value results when proactive benefits are built into the process. EMS audits such as the ISO 14001 EMS audit do not use a regulatory approach, instead they evaluate environmental aspects and impacts as opposed to compliance regulations (Hepler and Neumann, 2003). An EMS audit primarily determines whether an organization's EMS conforms to the criteria set by the organization, and communicates the results to management (Wilson, 1999).

Audits can provide significant benefits through their ability to stimulate interest and encourage improved environmental performance through raised awareness. Part of the shortfalls of existing audits is that they are either compliance or management based. Hepler and Neumann (2003) compared three different environmental audit tools to determine which was most appropriate for DoD facilities, using a United States Army Corps of Engineers unit as the prospective subject. They found that it would be most beneficial to use both an environmental compliance audit and an environmental management system audit to ensure that current requirements were being met and that the management was focused on continual improvement of environmental performance as a whole (Hepler and Neumann, 2003). The Marine Corps uses a hybrid type of audit which inspects both compliance and management requirements as defined by Federal, state, and local laws as well as DoD and Marine Corps environmental policy. This audit, known as the Environmental Compliance Evaluation (ECE), provides scores which are representative of the environmental posture of an individual Marine Corps installation at a point in time (DON, HQMC, 1998).

2.1.3. Organizational Motivators for Selecting Environmental Goals.

Once environmental policy and objectives have been established, effective measurement through audits and metrics can be used to show progress towards stated environmental goals (Richards, 1999). The environmental goal an organization has depends on that organization's strategy. Many managers have struggled with how to best handle compliance with environmental regulations, due to the tradeoffs between environmental and economic performance (Klassen and McLaughlin, 1996). Standard theory predicts that a firm will comply with a regulation when its compliance cost is less than the expected penalty associated with the violation (Friesen, 2003).

Organizations with a short-term focus are more likely to focus on meeting minimum environmental compliance standards as required by law. Those organizations that are larger, with a longer term focus are likely to perform beyond minimum compliance standards, and strive towards a higher level of environmental performance through process improvement (Klassen and McLaughlin, 1996). In the course of striving towards higher environmental performance, companies on the leading edge of their industry hope to recognize further business opportunities (Ramsey, 2002). In a 2001 RAND study, Camm reported that innovative organizations view a long term process focus as a way to turn environmental issues into strategic advantage (Camm, 2001). At times, environmentally responsible actions do bring higher costs such as purchasing equipment to reduce pollution. However, oft times cost savings can be realized through reducing waste streams in the manufacturing process, and overall operational efficiency increases as a result (Klassen and McLaughlin, 1996). Basically, each business decision involving environmental compliance is based on the marginal utility with respect to the overall mission and strategy of the organization. The marginal utility concept is epitomized in the recent practice of emissions trading, in which a company with lower-than-required toxic emissions of a specific pollutant 'sells' a loading reduction to another facility that cannot afford to meet the effluent limit through technological means (Hileman, 1999). In this way, facilities whose environmental performance exceeds the minimum standards, may turn the higher level of performance into a capital income through a trade with a facility which is not meeting the minimum compliance standards. The practice of emissions trading is currently in place for carbon dioxide, and nitrogen oxide, with discussions of including other types of pollutants in future years (Hileman, 1999).

Labat and Maclaren (1998) say that the key motivating factors behind EM efforts are a) threat of regulation, b) public image, c) financial considerations, and d) industry peer pressure. The degree to which the organization faces and accepts the influence of calculated, normative, and social pressures can affect their ultimate equilibrium compliance level. In organizational culture, while calculated motivators directly affect compliance, normative and social motivators are two underutilized focuses which can support compliance efforts (Winter and May, 2001). Calculated pressures act upon the fear of the organization that violations will be detected and punished. Normative pressures are tied to a civic duty to comply, and this can be bolstered if the organization has knowledge of the results of environmentally irresponsible facilities. Also, informal sources such as consultants have been a source of normative pressure in that they have been able to show how complying is in an organization's best interest by addressing compliance in conjunction with profitability. Social pressures act upon the desire of the regulated to earn the approval/respect of significant people with whom they interact.

Social pressures are increasingly coming from the general public as they have a direct stake in the relative health of the environment surrounding a facility if it is where they live (Winter and May, 2001). However, business insiders such as shareholders, suppliers, customers, and higher management can also influence an organization's cultural outlook upon the importance of compliance.

The concept of corporate environmental reporting (CER) has become an increasingly popular way for organizations to communicate their environmental compliance posture to concerned parties. Annandale, Morrison-Saunders, and Bouma conducted a study in 2004 to measure the effects of both an EMS and CER on environmental performance levels. Annandale et al. (2004) found that stakeholder pressure, regulatory pressure, and organizational culture were the most significant influences on environmental performance. Supply chain pressure (pressure from parent company and clients) may also have a greater influence than either an EMS or the use of CER. Whereas CER attempts to positively influence the way companies are viewed by stakeholders (external focus), EMS was seen as a more internal tool to influence environmental compliance and performance (Annandale et al., 2004).

Over the past 30 years there has been a general trend of striving for higher levels of environmental performance to improve operational efficiency as a whole. Industrial environmental practices have evolved from controlling pollution at the end of the pipe to, managing "eco-efficiently" and maximizing both economic gain and environmental performance. Eco-efficiency gives environmental considerations strategic importance rather than treating them simply as overhead (Richards, 1999). As industry has moved from pollution control to pollution prevention to eco-efficiency, there has been a corresponding evolution of goals. **Table 1** illustrates how environmental objectives have evolved over time.

Table 1: Evolution of Industry's Environmental Goals and Metrics (Richards, 1999: 25). The progression of environmental goals and associated metrics over time has reflected society's increasing interest in preserving the environment.

Pre-1970	Mid-1970s to Mid-1980s	Mid-1980s to Mid-1990s	2000 and Beyond
Goals			
• None	• Meet regulatory standards	• Cost avoidance • Emissions reduction • Preempt regulations • Image • Leadership • Legitimacy protection • Competitive edge	• Explicit mainstreaming of environmental goals - Design for environment - Life-cycle assessment - Environmental cost management - Recycling targets - Alternative products
Metrics			
• None	• As required by regulation - hazardous waste generation - permit violations - payout of regulatory fines	• As required by regulation • Rates and quantity of emissions • Energy efficiency metrics • Productivity improvement metrics • Toxicity reduction metrics	• As required by regulation • Rates and quantity of emissions • Energy efficiency metrics • Productivity improvement metrics • Toxicity reduction metrics • Recycle rates • "Weighted" metrics • Other

Sustainable development and design techniques are also emerging which support eco-efficiency; two well known environmental engineers and designers, William McDonough and Michael Braungart, have taken the eco-efficiency idea one step further by promoting a 'cradle-to-cradle' concept. The cradle-to-cradle concept encourages designers to create closed loop processes where the goal is to attain maximum resource efficiency while at the same time creating minimal wastes (McDonough and Braungart, 2002). Another contemporary approach in the business world seeks to balances economic and environmental goals with social goals, by creating a new "triple bottom line" (Richards, 1999). The triple bottom line is found through quantifying the expenditures and benefits of attaining environmental and social goals in the larger economic context of business operations. This signals part of a growing trend to integrate environmental matters into the mainstream of business decisions. Concepts such as the triple bottom line enable the relative costs and benefits of resource expenditures to be compared with other more commonly quantified measures of operational performance. Environmental goals are thus listed under the construct of larger business goals, and the costs and savings associated with each objective are evaluated (Richards, 1999).

2.2 Defining Contemporary Environmental Management

2.2.1. Explanation & Comparison of Different Environmental Management Approaches.

Environmental Management (EM) encompasses all efforts of an organization to minimize negative environmental impacts from products and services throughout their lifecycles (Klassen and McLaughlin, 1996). The purpose of an Environmental Management program is to develop, implement, manage, coordinate, and monitor corporate environmental activities to achieve the organization's stated environmental goals and objectives (Melnyk et al., 2003). Just as environmental goals and objectives depend on an organization's strategy, so does the way an organization chooses to set up its Environmental Management program (Tinsley, 2002; Klassen and McLaughlin, 1996). Figure 2, which was developed from research in the evaluation of Environmental Management programs, shows many different aspects which influence an organization's environmental management program.

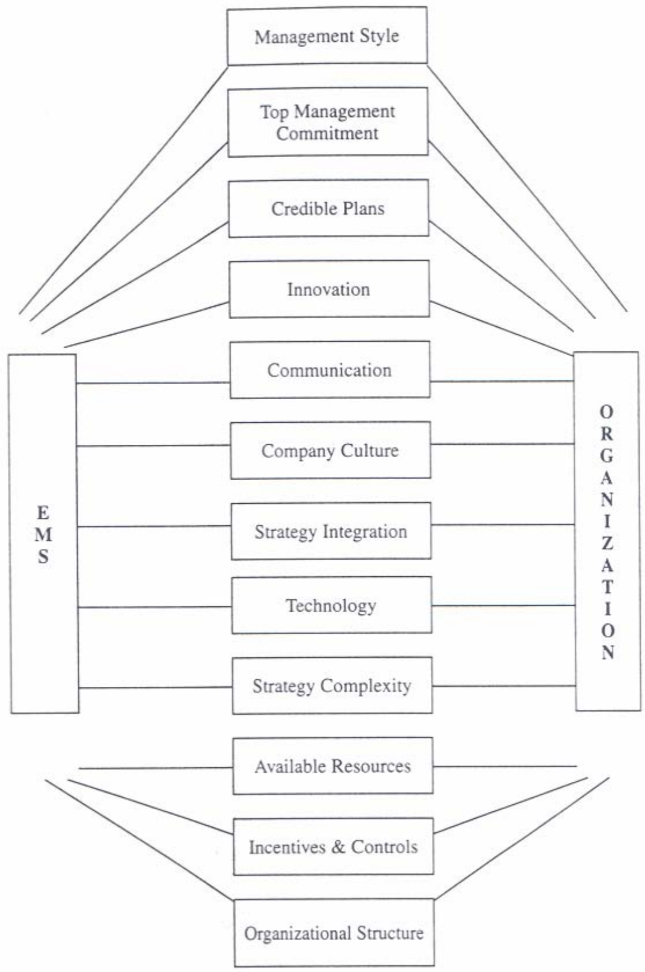


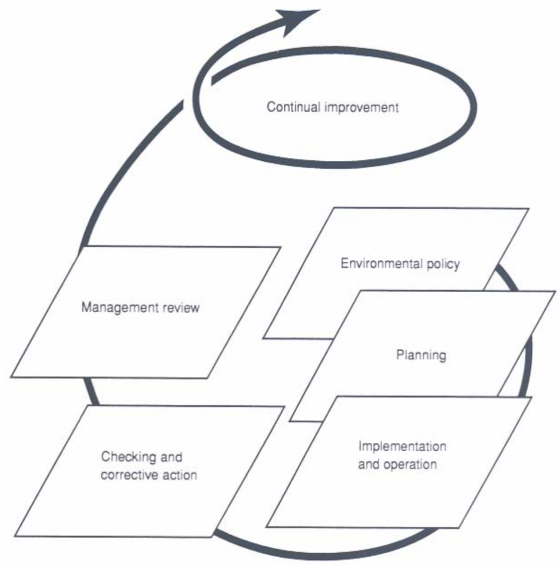
Figure 2: How Organizational Factors Affect an Environmental Management program (Tinsley, 2002: 377). The middle column represents organizational factors which determine the composition of an organization's EMS.

Initially, all Environmental Management efforts were aimed solely at achieving compliance. As organizations in the late 1980's and early 1990's began to view environmental awareness as a way to achieve a competitive advantage, industry began to examine ways to perform environmental management in a methodical way, so as to maximize its positive effect on organizational and financial performance. In 1993, Technical Committee 207 was formed by the International Standards Organization (ISO) to create the 14000 series standards, which describe a generic environmental management framework that could be used as a global standard (Block, 2001). The ISO, based in Geneva, is an international federation of "standards bodies" from 111 nations. It was founded in 1946 with the aim of promoting standardization in order to facilitate international exchange of goods and services (von Zharen, 1996). Historically, the ISO primarily addressed technical manufacturing standards. However, the ISO did address management standards in the creation of the ISO 9000 series which is a set of standards promoting quality control management. The quality control movement gained popularity in the 1980's as another way to gain competitive advantage within industry (von Zharen, 1996). Both the ISO 9000 and the ISO 14000 series used a systems approach to address general management issues within the subject area. The concepts of ISO 14001 mirror those of ISO 9001: requirement for a policy statement; top level management commitment; document control; employee training; corrective action; management review and continual improvement (International Standards Organization, 1996). The official ISO 14000 series, released in 1996, is a set of standards which outline the framework and operation of environmental management systems (EMSs). Some specific standards in the 14000 series that pertain to EMSs are shown in Table 2.

Table 2: Some Individual Standards Contained in the ISO 14000 Series (von Zharen, 1996: 16-17). The ISO 14000 series provides specific requirements and principles for environmental management through a specification standard (14001) as well as other guidance standards.

Standard	**Title/Description**
ISO 14001	Environmental Management System Specification
ISO 14004	Environmental Management General Guides on Principles, Systems, and Supporting Techniques
ISO 14010	Guidelines for Environmental Auditing - General Principles
ISO 14011	Guidelines for Environmental Auditing - Auditing of Environmental Management Systems
ISO 14012	Guidelines for Environmental Auditing - Qualification Criteria for Environmental Auditors
ISO 14031	Evaluation of the Environmental Performance of the Operational System and Its Relationship to the Environment

The focus of the ISO 14001 standard is on the processes involved in the creation, management, and elimination of pollution. Figure 3 illustrates the five major requirements of an EMS which are outlined in the ISO 14001 specification: 1) Environmental policy, 2) Planning, 3) Implementation and operation, 4) Checking and corrective action, 5) Management review and how all the requirements support the idea of continual improvement.



ISO 14001 EMS Elements

1. A *Policy Statement* endorsed by top management.
2. *Planning*: identifying how operations impact the environment, setting goals and targets for reducing impacts, tracking legal and other requirements, and developing systems for environmental management.
3. *Implementation and Operation:* assigning roles and responsibilities, training, communication, documentation, and emergency preparedness.
4. *Checking and Corrective Action:* establishing ways to monitor, identify and correct environmental problems.
5. *Management Review* focused toward continuous improvement.

Figure 3: EMS Model for ISO 14001 (International Standards Organization, 1996: 2). The interaction of the five elements of an EMS is illustrated on the left, while a further explanation of the model elements is offered on the right.

For those organizations which follow the environmental management framework suggested by the ISO 14001 standard, three related tasks are required (Block, 2001):

- An organization must be familiar with all legal requirements and have a mechanism for ensuring that they are aware of new legal obligations as they come into existence.
- The environmental policy must state the organization's commitment to understand and comply with all applicable laws and regulations.
- Compliance with identified legal requirements must be evaluated on some self-defined periodic basis. This may be through regular metrics or a comprehensive compliance audit. Either way if a noncompliance is discovered, the organization must take action to correct noncompliance and prevent it from recurring

It is important to note that the ISO 14001 standard is based on processes, not performance, and as such, the system is designed to help an organization achieve its own stated environmental objectives, whatever they may be (Melnyk et al., 2003). Because these requirements do not impose specific performance standards on organizations; individual organizations must define their desired level of environmental performance within the context posed by national, state, and local laws (Block, 2001). While the original version of the ISO 14000 standards were published in 1996, those same standards were reviewed in 2001 as part of an ISO effort to keep all standards current through a five year review process. With the second edition of the ISO 14000 standards due out at the end of 2004, it seems the changes to the original will be minor and most changes are aimed at clarifying the language and intent of various passages. It appears that the framework initially established by the ISO will remain intact, based off of the draft version of the document which was released for review in the spring of 2004 (Block, 2004).

In the available spectrum of environmental management structures that are available to an organization, it is important to distinguish between three different types: an Environmental Management program, a formal Environmental Management System, and a certified Environmental Management System. For purposes of this thesis, an EM *program* is construed as a structure which is the least robust and most informal of the available management structures. Environmental management programs are 'homegrown' by the organization to specifically address the environmental requirements of that organization, and they are usually focused on outcomes. An environmental management *system* is a more robust management structure which focuses on processes. Furthermore, an EMS provides for organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for implementing and maintaining environmental policy (von Zharen, 1996). An EMS includes the same 5 major sections as the ISO 14001 standard. The most robust form of environmental management structure is the *certified* EMS. If an organization's EMS fulfills all requirements stated by the ISO 14001 standard, the organization may submit its EMS for review through a formal third party audit process. If the auditor finds that all requirements of the ISO 14001 standard are being met, the organization's EMS is 'certified' which announces that organization's environmental management efforts are structured for continual improvement beyond minimal levels of compliance (von Zharen, 1996).

2.2.2. Environmental Management Policy & Standards within the DoD and USMC.

The evolution of environmental management within the Federal government has somewhat paralleled the progress seen in the private sector during the 1990s. While initial environmental management efforts were aimed at compliance, increasingly the Federal government encouraged, then directed agency participation in EMSs. Various Executive Orders (EOs), including 12873 and 12856, passed in 1997, as well as 13148 which was passed in 2000, were instrumental in guiding Federal agencies towards developing sound environmental management practices. Figure 4 provides a list of the larger, commonly recognized Federal agencies that are affected by these Executive Orders.

Central Intelligence Agency (CIA)	Environmental Protection Agency (EPA)
Department of Agriculture (USDA)	General Services Administration (GSA)
Department of Commerce (DoC)	Health and Human Services (HHS)
Department of Energy (DoE)	Postal Service
Department of Interior (DoI)	Tennessee Valley Authority (TVA)
Department of Justice (DoJ)	US Department of Defense (DoD)
Department of Transportation (DoTransp.)	Veterans Administration (VA)
Department of Treasury (DoTreas.)	

Figure 4: Prominent Federal Agencies (Federal Facilities Enforcement Office 1997: 55). These Federal Agencies have developed environmental management policies in accordance with guidance contained in various Executive Orders.

In 1993, when ISO Technical Committee 207 was formed to create a generic EMS framework, two Executive Orders were passed which provided the foundations for future environmental management efforts within the Federal government. The Office of the Federal Environmental Executive (OFEE) was established by Executive Order (EO) 12873, "Federal Acquisition, Recycling, and Waste Prevention." The OFEE mission is to promote sustainable environmental stewardship through the Federal government and to serve as an information source to a diverse array of Federal agencies (Block, 2003). Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," required the Federal government to implement certain pollution prevention measures, and to publicly report and reduce the generation of toxic and hazardous chemicals and associated emissions. It also contained the requirement for the EPA to develop a program which emphasized pollution prevention and state-of the-art environmental management principles.

The Code of Environmental Management Principles for Federal Agencies (CEMP), was developed by the EPA in response to Executive Order 12856. The CEMP is a collection of five broad principles and underlying performance objectives that provided a basis for Federal agencies to move toward responsible environmental management. These principles are listed in Figure 5 (Federal Facilities Enforcement Office, 1997).

CEMP Principles

1. Management Commitment: The agency makes a written top-management commitment to improved environmental performance by establishing policies that emphasize pollution prevention and the need to ensure compliance with environmental requirements.

2. Compliance Assurance and Pollution Prevention: The agency implements proactive programs that aggressively identify and address potential compliance problem areas and utilize pollution prevention approaches to correct deficiencies and improve environmental performance.

3. Enabling Systems: The agency develops and implements the necessary measures to enable personnel to perform their functions consistent with regulatory requirements, agency environmental policies, and its overall mission.

4. Performance and Accountability: The agency develops measures to address employee environmental performance, and ensure full accountability of environmental functions.

5. Measurement and Improvement: The agency develops and implements a program to assess progress toward meeting its environmental goals and uses the results to improve environmental performance.

Figure 5: CEMP Principles (Federal Facilities Enforcement Office, 1997: 4). These principles were created by the EPA to aid Federal agencies in managing environmental matters in a more responsible manner.

The CEMP, published in March of 1997, was meant to provide guidance to Federal agencies to improve overall performance while maintaining compliance as a performance baseline. The goal of the CEMP was to move agencies beyond compliance and the traditional short-term focus on regulatory requirements to a broader, more inclusive view of interrelated nature of their environmental activities (Federal Facilities Enforcement Office, 1997).

The foundation for EMSs at the Federal level can be traced back to 2000 and the signing of Executive Order 13148, “Greening the Government Through Leadership in

Environmental Management" (Block, 2003; Hepler and Neumann, 2003). Executive Order 13148 formalized the following requirements (President, 2000):

- The head of each Federal agency is responsible for ensuring all necessary actions are taken to integrate environmental accountability into agency day-to-day decision making and long-term planning.
- Strategies to support environmental leadership are established through development and implementation of EMSs. The EMS must be formulated based on agency environmental goals and objectives, while meeting all applicable compliance requirements.
- Agencies must base their EMSs on the CEMP or another "appropriate" EMS framework, such as the ISO 14001.
- By December 31, 2005, each agency must implement an EMS at all appropriate agency facilities based on facility size, complexity and the environmental aspects of facility operations.

In 2002, the Bush administration expanded the role of the OFEE beyond waste prevention and recycling to address a broader set of sustainability issues in the Federal government. In 2002, OFEE formally reemphasized the requirement to develop and implement EMSs throughout the Federal government (Block, 2003). The Department of Defense (DoD) as a Federal agency acknowledged the guidance contained in the Executive Orders, and tasked the military service to create environmental management programs accordingly. Subsequently each military service has developed its own version of environmental management which fulfills the requirements of the aforementioned Executive Orders and policy directives. As this thesis effort evaluates environmental management in the context of the Marine Corps service, the following section addresses the evolution and current structure of the Marine Corps environmental management program.

In response to the requirements of DoD environmental policies, Marine Corps Order P5090.2A, "Environmental Compliance and Protection Manual," (ECPM) was released on July 10, 1998 (DON, HQMC, 1998). The ECPM outlines the requirements of Federal environmental regulations, as well as establishes Marine Corps policy for funding and evaluating environmental compliance and environmental management programs at Marine Corps installations. A series of appendices group all applicable environmental requirements into seven groups by their sources (DON, HQMC, 1998):

a. Federal Statutes: Major environmental laws
b. Federal Regulations: Title 40 of the Codes of Federal Regulations, and other CFRs which are pertinent to the environment
c. Executive Orders
d. DoD Directives and Instructions
e. Secretary of the Navy Instructions
f. Naval Facilities Publications
g. Marine Corps Orders

The ECPM is a useful aid to identify potential sources of environmental compliance and management regulations that may apply to a Marine Corps installation. Of particular interest are the second, fourth, and fifth chapters which cover, Environmental Management, the ECE audit program, and Environmental Training and Education guidelines, respectively. Other chapters of the ECPM cover specific areas of environmental compliance, such as Natural Resources Management, Pollution Prevention, and Water Quality Management.

The second chapter of the ECPM is devoted to the Marine Corps' Environmental Management program. The chapter addresses various policy requirements which aim to keep the Marine Corps within compliance. Marine Corps installations and commands promote environmental training and education, pollution prevention, and integrated management of natural resources as part of a long-term strategy for achieving and maintaining environmental compliance. For example, for pollution prevention, responsible parties are to identify means and methods for the elimination or minimization of pollutants, particularly hazardous wastes, using the following hierarchy: 1) source reduction, 2) material recycling, 3) treatment, and 4) disposal. To better clarify and communicate these policies, installation commanders have published environmental compliance and protection standard operating procedures (ECPSOPs) to provide guidance to all subordinate commands on how to perform their missions in an environmentally sensitive manner (DON, HQMC, 1998).

Environmental management within the Marine Corps has a strong foundation of management commitment, integration of environmental affairs throughout the different units which work together, and communication up and down the chain of command in order to promote environmentally responsible behavior. At the top level, Regional Environmental Coordinators (RECs) coordinate the consistent interpretation and application of DoD environmental policies within the region in consultation with other military commands and units in the same EPA region. The RECs are the primary interface with state, regional, and Federal regulatory agencies. They monitor state environmental legislation and regulations for impact on Marine Corps operations, while keeping all Marine Corps commands informed on agreements, permit conditions, and responses to regulatory agencies within the region (DON, HQMC, 1998).

The Marine Corps commitment to environmental efforts is communicated when the Commandant Marine Corps periodically publishes environmental policy statements to major commanders. These commanders then delineate the policy with respect to applicable environmental requirements to their individual commands. Marine Corps installations have also developed internal mechanisms to detail the responsibilities of Marine Corps commands and tenant organizations on an installation. The installation staff helps to advise on environmental issues such that the commands and tenants meet all applicable environmental requirements and participate in the host ECE program. Furthermore, if there is an occasion that a unit generates or handles hazardous material or waste, the commanders are required to designate an individual as the Hazardous Materials/Hazardous Waste officer. All major Fleet Marine Force commands are encouraged to retain an Environmental Engineering Management Officer to coordinate environmental activities conducted by the tenants aboard the installation in conjunction with the installation environmental staff (DON, HQMC, 1998).

The Marine Corps also recognizes the importance of recordkeeping and administrative support in maintaining a high performing environmental management program. Marine Corps policy makes provisions for turnover files as well as the maintenance of files and reports on environmental materials (DON, HQMC, 1998). The requirement for turnover files dictates that all personnel with environmental responsibilities keep a binder with all pertinent requirements, information on operations, etc., that explain the environmental duties of their position and unit. These ‘desktop procedures' ensure that knowledge is retained and a continuity of effort through shifts and rotations of both military and non-military personnel. The environmental staff is also required to be audited every two years to ensure proper recordkeeping procedures are being followed. The audit examines the centralized control system for long-term records. Internal filing and publication control is conducted as prescribed by applicable Secretary of the Navy Instructions and Marine Corps Orders. The Marine Corps recognizes that the documentation of events, policies, and procedures, as well as receipts, reports, and studies, are particularly important elements in demonstrating the intent to comply and actual compliance with procedural and administrative environmental requirements. This second chapter of the ECPM provides many of the requirements that are contained in the Policy Management area of an ECE (DON, HQMC, 1998).

Audit procedures are addressed in-depth in the fourth chapter of the ECPM, which covers the Marine Corps environmental audit program, the Environmental Compliance Evaluation (ECE). Despite the name, the ECE covers both compliance and management issues within the audit. While the compliance requirements are derived from Federal, state, and local regulations, the management requirements contained in ECEs are derived from DoD, DoN, and Marine Corps policy. This chapter provides many of the requirements that are contained in the Audit Management area of an ECE. The intricacies of the audit program are covered in conjunction with the methodology which is presented in chapter three of this thesis (DON, HQMC, 1998).

The fifth chapter of the ECPM addresses various training requirements, plans, and procedures which aim to ensure that training and information are available, efficient, and effective in preparing Marine Corps personnel to perform their duties in an environmentally conscious manner. In recognition of the intricacy and importance of environmental training, the Comprehensive Environmental Training and Education Program (CETEP), was developed in 1997. CETEP uses established Marine Corps training and leadership concepts and procedures to characterize and address environmental training requirement. CETEP is a clever innovation because it integrates education on environmental matters, which may be somewhat foreign to the average Marine, into the Marine Corps' standard training program format which is widely known and recognized by most Marines (DON, HQMC, 1998).

Each installation must have a formal, written CETEP in order to create a well rounded environmental training program which supports Marine Corps environmental objectives. Components of each CETEP are based off the common sense need for certain occupations with environmental impacts to receive training as well as training requirements derived from legal sources. Several Federal statues that have major training requirements are listed for reference in chapter five, including the Resource Conservation and Recovery Act (RCRA) and the Hazardous and Solid Waste Amendments, the Occupational Safety and Health Act (OSHA), as well as the Federal Facilities Compliance Act among others. Table 3, taken from chapter five of the ECPM, organizes several of these explicit environmental training requirements (DON, HQMC, 1998).

Table 3: Explicit Environmental Training Requirements Affecting the Marine Corps (DON, HQMC, 1998, 5-31). This table from chapter five of the ECPM organizes the environmental training requirements that stem from some prominent Federal statutes, including RCRA and OSHA among others.

	RCRA Large Quantity Generators	RCRA Small Quantity Generators	DOT	OSHA Hazard Communication Standard	OSHA Hazardous Waste Operations and Emergency Response	Spill Prevention, Containment and Countermeasures (SPCC)
Applicability	Facilitities that generates more than 1,000 kg/month of hazardous waste	Facilities that generate from 100 to 1,000 kg/month of hazardous waste	Facilities involved in the transportation, shipment, or preparation for shipment of hazardous materials.	Facilities that handle hazardous chemicals	Facilities that may be involved in an emergency response operation involving the release of a hazardous substance	Facilities required to prepare a SPCC Plan
Who Must Be Trained	Employees who handle hazardous waste	Employees who handle hazardous waste	Employees involved in the transportation or shipment of hazardous materials/wastes	Employees who may be exposed to hazardous chemicals under normal operating conditions or in foreseeable emergencies	Employees who participate, or may be expected to participate, in emergency response; training based on level of involvement	Employees involved in the operation and maintenance of equipment that may discharge oil
When Training Must Occur	Within 6 months after employment or new job assignment; must be supervised until trained. Annual refresher for allemployees.	Not specified	Within 90 days after employment or new job assignment 49 CFR 172-704(c)	At time of initial assignment. Whenever a new hazard is introduced to the work area	Initial training prior to taking part in emergency response. Annual refresher	Spill prevention briefings must be conduted "at intervals frequent enough to assure adequate understanding of the SPCC Plan"
Record-keeping	Written job title and job description; written description of training required for each position; documentation that training has been provided	Not required	Written description of employee information including certification 49 CFR 172-704(d)	Written description of employee information and training must be included in hazard communication program	Must certify training or competency, including method used to demonstrate competency	Logs of personnel attending and topics discussed in training sessions are required.
Regulatory Citation	40 CFR 262.34(a)(4) 40 CFR 265.16	40 CFR 262.34(d)(5)(iii)	49 CFR 173.1(b); 49 CFR 177.800(a); 49 CFR 177.816; 49 CFR 172-700-704	29 CFR 1910.1200(b)(h)	29 CFR 1910.120(q)(5)(6) 29 CFR 1910.120(p)(7) and (p)(8)(iii)	40 CFR 112.7(e)(10)

Marine Corps environmental training policy under CETEP promotes not only explicit training which expressly required by law but also encourages implicit training which is not required, but can be reasonably inferred as necessary due to the nature of work, licensing requirements, or certification requirements. CETEP also contains an Environmental General Awareness component, which seeks to alert all Marine Corps personnel to their potential interactions with the environment. It acknowledges that awareness and understanding of applicable environmental regulations is a necessary precursor to personnel taking actions in consonance with pollution prevention, compliance, and other environmental goals. This chapter of the ECPM provides many of the requirements that are contained in the Training Management area of an ECE (DON, HQMC, 1998).

2.3 Environmental Management Principles Thought to Influence Environmental Compliance & Performance Levels

2.3.1. Robustness of Environmental Management Efforts.

Environmental management programs within organizations vary as to their degree of formality, the amount of resources that are invested in them, and the degree to which they are integrated with other functional departments. The robustness of an Environmental management program usually depends on the importance of its environmental status. If meeting minimum compliance standards is an organization's main environmental goal, it is likely that the resources put into an Environmental Management program and staff will be less than an organization that is striving for higher levels of environmental performance. Generally speaking, informal programs with few resources (in terms of staffing and funding), which are not integrated into the organization have a weaker influence on an organization's environmental performance, than an organization with a formal program and an adequate environmental staff.

A number of studies have been done to indicate the effectiveness of an EM program or EMS in positively influencing the level of compliance in an organization. The Multi State Working Group (MSWG), an organization of state environmental agencies, was formed in 1996 by the EPA to evaluate environmental management issues in different regions across the US. One of the focuses of the MSWG was to determine whether ISO

14001 registration results in improved regulatory compliance (Block, 2001). Results of the MSWG group were inconclusive, but a group of ISO 14001 registrars indicated that (Block, 2001):

- In efforts to identify all legal requirements, an increased level of awareness causes organizations to become compliant in areas previously ignored.
- Periodic evaluation of compliance requirements creates an operating climate in which responding to regulatory lapses is considered standard operating procedure.

Montabon et al., (2000) preformed a large scale survey of American managers, to test the idea that the more robust EMS format seems to outperform EM program models. In organizations with an environmental management program, environmental management is portrayed as a separate activity, internally focused, driven by regulations, and reactive in nature. They found that in many cases the environmental management program was reactive, because it responded to problems only when they emerged and became of critical importance. Also, EM program updates were primarily driven by changes in environmental regulations as opposed to original or integrated thinking, as in the case of EMSs. In looking at more robust environmental management efforts, including organizations with formal EMSs and certified EMSs, Montabon et al (2000), found a strong positive correlation between the stage of ISO 14000 certification and the effectiveness of the EMS when tested upon various dimensions of operational performance. The closer the firm was to attaining ISO 14001 certification, the greater the positive impact the EMS had on the overall performance of the firm.

Melnyk et al., (2003) performed a study where self-reported measures of performance from plant-level experts within the US were used to gauge the effectiveness of different types of environmental management structures. Improved environmental performance was gauged by reduced costs, improved quality, reduction of waste in the design and equipment selection process, and reduction of lead times. The study found that a certified EMS was most effective, followed by a formal EMS, followed by informal EM programs in achieving high levels of corporate performance (Melnyk et al., 2003). Both Melnyk et al. (2003) and Montabon et al. (2000) identified common factors in why a certified EMS was better than less robust EM programs, which include the following:

- The act of a plant wide certification involves many people in different positions and functions. The process of being certified requires organization personnel to formalize environmental procedures in order to demonstrate that written policy is known and followed by all departments within a facility.
- The benefits are generated from focusing on underlying processes (longer term focus) as opposed to just outputs (short term). Decreased level of pollution can decrease disposal costs which can increase operational performance. Since ISO is process oriented rather than output based, firms pursuing certification end up changing underlying processes resulting in more efficient processes, less waste and pollution.
- Environmental evaluation by a third party may be an incentive for all employees to try harder. For an organization to fulfill certification requirements, all employees would have to be aware of their impacts on the environment, whether they are directly or indirectly responsible for environmental affairs.

Melnyk et al.(2003) also found that the use of a more robust EMS as compared to a formal EMS or informal EM program promoted the use of a broader range of environmental options during problem situations. In general, personnel in certified facilities were more aware of opportunities available for the more effective and efficient disposal of waste through proactive process or design changes. Whereas in uncertified facilities, personnel were less creative in considering options to improve environmental performance, and they more frequently used reactive options. Also, as the age of the program increased, the more experienced firms were better than the less experienced firms in exercising environmental options (Melnyk, 2003).

2.3.2. Successful Environmental Management Principles.

Through a synthesis of popular literature surrounding successful environmental management processes, specific principles were emphasized repeatedly in conjunction with high levels of compliance and/or performance. These principles of management commitment, employee awareness & comprehension, administrative attention, systems approach, integration of environmental affairs into operation, seem to be the parts of an EM program or EMS which really drives accomplishments and improvements. Each management principle is detailed below.

Management commitment.

An active management commitment ensures that ongoing attention is devoted to environmental matters within the organization. One way to accomplish this is to designate a senior company officer for environmental, health, and safety compliance. This also establishes accountability for environmental management which specifically tasks an employee with the environmental status of the organization. (Garvin, 1996). The personal touch of an environmental coordinator can also be useful in establishing and maintaining good working relations with regulatory agencies. Since organizations frequently need to negotiate when applying for a permit or to reduce proposed penalties, good will goes a long way towards results in favor of the organization (Wei, 2002).

Employee awareness and comprehension.

The ability to promote awareness of environmental regulations, issues, and goals across the organization is a key component in effective environmental management, as the actions of several employees can serve to enhance or detract from the environmental posture of a facility. This awareness can be accomplished by integrating environmental policies into broader corporate culture (Camm, 2001). An EMS can also affect a company cultural change through internal process reform (Annandale, 2004). Obviously, the availability of environmental information is a precondition to compliance. A minimum threshold level of awareness of regulations and what their requirements mean to a facility is required before employees can be expected to comply with regulations. The threshold differs depending on the precision and complexity of the regulation and how it might apply to a facility's operations, and a specific employee's job tasks (Winter and May, 2001). If the organization's culture is receptive to the efforts of outside regulators and it empowers its environmental staff to provide information and guidance to other departments within the organization, then compliance levels are positively affected. Requests for information or trouble reporting can be addressed through a forum where employees can voice concerns on environmental issues. A study by Malmborg (2002), argues that while EMS may be used as a technical tool for analytic management, a formal EMS may also be a useful tool for communicative action and organizational learning.

The next step towards comprehension involves helping all members of an organization to understand what environmental requirements mean to them. There is a marked difference between announcing a set of neutral facts about requirements and providing training and guidance on environmentally responsible actions. Creating an environmental training program can help to ensure that employees understand environmental requirements. The type of specific training depends on the responsibilities of the employees – the level of training should be matched to specific skills and tasks that an employee uses for his/her job. Another goal of training can be to instill personnel with ownership of environmental performance within their work center (Garvin, 1996; Wei, 2002).

Administrative attention.

Several types of administrative actions such as environmental policy, plans, and procedures, as well as recordkeeping and audit requirements can contribute much to the success of environmental management. Establishing a written environmental policy is an excellent means to communicate your environmental objectives and the accompanying plans and procedures to attain those objectives to employees while also showing management commitment to environmental matters (Garvin, 1996; Wei, 2002). Hepler and Neumann (2003) note that achievement of high levels of environmental performance will be unlikely unless an environmental management plan is first developed. They propose that a properly designed and executed environmental management plan considering both management and compliance issues would lead the organization into resource conservation and produce high levels of performance (Hepler and Neumann, 2003). Developing an environmental plans and procedures manual containing all pertinent environmental regulations, schedules, permits, and company environmental points of contact can also help in organizing and maintaining environmental records. The procedures describe steps that are taken as a part of everyday operations to fulfill environmental requirements. The employee environmental-response plan provides guidance on what to do in the case of a spill or accident. The best response plans are those that are straightforward and easy to implement (Garvin, 1996; Wei, 2002).

Detailed recordkeeping is required in environmental management to monitor and document the changing environmental status vis-à-vis the changing environmental requirements on a regular basis. Retaining detailed records to document the type and quantities of chemicals in use can be used in the planning process. In certain cases, paperwork must be kept, as in the case of hazardous waste manifests, to prove that the material was shipped off site and to fulfill compliance requirements (Garvin, 1996). Regular measurement and recording of environmental data may be useful in, or required for, Corporate Environmental Reporting. Having this information available is essential to meeting and managing compliance and performance from external sources, such as shareholders, customers, and the general public.

Conducting regular environmental audits is another key administrative action which can aid in boosting compliance levels. Audits require an organization to identify all applicable environmental laws and regulations which is the first step in attaining compliance (Garvin, 1996). Wei (2002) recommends staying current with environmental regulations by visiting the EPA and state environmental websites once a week. Environmental audits are most useful when they are conducted by independent contractors or impartial employees, because they offer an impartial assessment of an organization's environmental posture (Garvin, 1996; Hepler and Neumann, 2003). Additionally, Eckert (2004) has found that cumulative environmental inspections do have a direct negative response on the probability of a violation. If an organization knows it will be inspected in the near future, according to Eckert (2004), there is an average of

20% reduction in noncompliance areas. Environmental audits can serve as an educative tool to better show how a regulation applies to a given facility or operation (Eckert, 2004).

It is important to note that both environmental compliance audits as well as environmental management audits may both have a positive impact upon the future compliance of an organization. Helper and Neumann (2003) note that some audits, such as the EPA's Generic Environmental Audit attempt to find non compliance issues, and organizations can then become more compliant by correcting noted deficiencies. Regulatory based audits are good to police nonconforming facilities, but they do not seek the root causes of non compliance. Audits of this type are not expected to achieve high levels of performance beyond baseline compliance levels. Identifying deficiencies is only the first step - real audit value results when proactive benefits are built into the process. EMS audits such as the ISO 14001 EMS audit do not use a regulatory approach, instead they evaluate environmental aspects and impacts as opposed to compliance regulations. Hepler and Neumann (2003) conclude that part of the shortfalls of existing audits is that they are either compliance or management based. In their study they concluded that the best combination of audits was the ISO 14001 EMS Audit and the Global Reporting Initiative (GRI) Environmental Performance. This thesis focuses on the Marine Corps ECE, a well balanced audit which includes both compliance and management requirements to examine the overall environmental compliance and management status of Marine Corps installations.

Systems approach to environmental decisions.

Using a systems approach involves accounting for and examining all pertinent environmental aspects, issues, and objectives in a holistic manner to achieve an understanding of the big picture. This approach allows a manager to explore an array of environmental options, and to select the option which best fits the plant's environmental objectives in the larger context of operational strategy (Garvin, 1996; Wei, 2002). Systematically evaluating plant operations and how environmental costs are allocated can also lead to improved compliance as well as cost savings. In a large facility that serves many product lines and products, the company generally allocates the cost of waste treatment to all products according to production volume. If one or two product lines or product cause most of the pollution, their production costs will not reflect this disproportionate share of the total environmental cost. A good strategy is to eliminate marginal products or processes that generate a disproportionate amount of pollution (Singh, 2000). An environmental manager may work with in house engineers during the research and development process to try to minimize the use of environmentally hazardous materials in new products and processes, thereby reducing waste disposal costs (Singh, 2000).

Another way to utilize a systems approach is in the consideration of supplier and vendor partnerships. Exercising due diligence in the final selection of waste disposal and treatment contractors can be a way to verify that they are reputable, keep good records, and have good relations with regional regulators (Garvin, 1996; Wei, 2002). Since EMSs are based on systematic evaluation and improvement, it is of little wonder that they have aided organizations in reaching higher levels of compliance and performance.

Improvements in recycling programs, energy efficiency, noise/dust abatement, spill management, and the development of environmentally friendly products and processes have been made through the introduction of an EMS to an organization (Annandale, 2004).

Environmental options can be created and evaluated through the use of financial models. There have been a number of efforts in recent years to quantify environmental expenditures and environmental performance, and to link the two areas to operational expenditures and performance. Many difficulties have been met in assigning and weighting costs and benefits associated with environmental options. One way is to use a delayed-expenditure model to evaluate financials beyond immediate costs. By comparing the costs and benefits, an organization can find the best time to make capital expenditures on environmental options. An organization can use such a model to find the best time to install pollution control equipment or to upgrade production technology. Careful planning can ensure that updates to production technology improve environmental compliance, reduce environmental costs, and reduce production costs through increased efficiency. Singh (2000) found that when regulation changes are imminent, updates to production technology should be planned and commenced before new regulations take effect. While an organization may benefit by postponing a capital expenditure, presumed benefits may turn into losses when compliance violations occur and the regulators assess penalties (Singh, 2000).

Integration of environmental concerns into operations.

Environmental management also seems to be more effective when environmental goals and objectives are integrated within the larger operational and management context.

Environmental managers are given responsibility to achieve and maintain environmental compliance, but frequently their hands are tied by the way responsibilities at the plant level are organized. Business and environmental changes are fundamentally interwoven, as changes in plant operations affect the quality and quantity of environmental discharges, and thus the cost of environmental compliance. In a complementary fashion, changes in environmental regulations may place limits on production, make it harder to use certain raw materials or particular technologies, or force a plant to chance its production processes. A truly integrated approach to environmental management coordinates the activities of the environmental staff with those of other functional departments in order to make sound business decisions (Singh, 2000). This integration evaluates new regulations, plant operations, emerging technologies, changes in markets, and fluctuations in product demand simultaneously to find solutions that best address both environmental compliance and production concerns. Consequently, the decisions made often reduce the costs in both areas. In this holistic approach, environmental requirements become a criterion for making business decisions, and business needs become criteria for making environmental decisions (Singh, 2000).

2.4 Summary

In summary, this literature review was conducted to identify existing links between environmental management and environmental compliance as identified by other researchers. The evolution of contemporary environmental compliance and performance was traced through the past 30 years. Methods for assessing the compliance levels include the use of metrics as well as environmental audits. Organizational motivators for environmental goals include an organization's strategy, as well as the organizational culture. Environmental goals in the short term are usually based on maintaining compliance, while long term environmental goals are increasingly focusing on building a competitive advantage through attaining higher levels of environmental performance. Next, different types of environmental management approaches were detailed ranging from informal environmental management programs to more formal environmental management systems (EMSs) to EMSs attaining certification under the ISO 14001 standard. Specific environmental management requirements which apply to Federal agencies, particularly the DoD, DoN, and Marine Corps were also discussed. The last part of the literature review identified successful environmental management principles including management commitment, employee awareness and comprehension, administrative actions, a systems approach, and integration of environmental affairs into operations, as key elements linked to high levels of environmental compliance.

III. Methodology

3.1. Problem Summary

In the past, the Marine Corps had no formal environmental management system (EMS) which was known outside of an installation's environmental office. Environmental management policies in the Marine Corps are in the process of evolving from a more reactive compliance-based approach to those that take a more preventive and proactive approach. Environmental noncompliance can have negative consequences such as fines, civil lawsuits, negative publicity, or periodic limitation of land use which could hinder vital training operations. Effective management of environmental compliance at Marine Corps installations includes steps to prevent and resolve compliance deficiencies by focusing on the most influential and relevant noncompliance factors and making appropriate investments to assure compliance. Effective management may also include steps to improve the existing environmental management structure to attain higher levels of environmental performance above and beyond what is required by applicable laws and regulations. It has not always been clear what environmental management functions may have the most influence on ensuring high levels of environmental compliance. By determining this relationship, environmental managers at Marine Corps installations can make more effective and efficient decisions to attain and maintain environmental compliance.

3.2. Summary of Method

The Marine Corps performs a benchmark Environmental Compliance Evaluation (ECE) every three years to evaluate if an installation is operating within parameters set by local, state, and Federal environmental regulations as well as DoD, DoN, and USMC environmental policies. In years when a benchmark ECE is not performed, the local environmental staff performs an environmental self-audit of the installation they are responsible for. The results of these regular environmental audits are used by the installation Commanding Officers/Commanding Generals and HQMC personnel to assess the levels of environmental management and environmental compliance at each Marine Corps installation. This study analyzes the ECE records over a seven year period from 1998 through 2004 to reveal and characterize existing relationships between management and compliance.

3.3. Collection of Data

3.3.1 Environmental Compliance Evaluation (ECE) Format/Components

The ECE program is governed by Marine Corps Order P5090.2A, the Marine Corps Environmental Compliance and Protection Manual (ECPM). Created in July 1998, the ECPM presents an overview of environmental responsibilities and provides guidance and instruction on how to fulfill environmental requirements for Marine Corps installations. Additionally, the ECPM summarizes all pertinent DoD requirements relating to environmental management responsibilities. The regulation sets forth Marine Corps specific environmental management requirements, the source of all the environmental management inspection questions included in a benchmark ECE. Chapter four of the ECPM specifically addresses the requirements for annual environmental audits through the ECE program (DON, HQMC, 1998).

ECEs are primarily designed to evaluate the environmental compliance and protection status of Marine Corps installations and provide information on those areas that require further attention to meet applicable laws, regulations, and directives. Originally, ECEs only included questions based on environmental compliance requirements which were derived from Federal, state, and local laws and regulations. However, the ECPM was later revised to include additional environmental management requirements derived from both DoD and service policies. Therefore, in the first benchmark ECEs that were performed from 1995 to 1997, only compliance questions were included on evaluation checklists. After the passage of the ECPM in 1998, ECEs included management questions as well. From 1995 to present, this created three groups of evaluation data based on the triennial schedule of ECEs, where most installations were inspected one time within each time series (A, B, and C), as detailed below:

- A series data: covering 1995-1997, includes compliance categories only,
- B series data: covering 1998-2001, includes compliance and management categories,
- C series data: covering 2001-2004, includes compliance and management categories.

The present day ECE provides a snapshot environmental profile based on representative data and sampling in 15 different compliance categories and one management category, as shown in Table 4.

Table 4: ECE Areas, Categories, and Subcategory Listing with Codes. The subject matter of ECE questions are classified into a hierarchy of area, then category, then subcategory, where three letter acronyms represent each classification level.

	Media Areas (Category-Subcategory)	
Area	Categories	Subcategories
Compliance	Air (AIR)	Asbestos (ASB), General (GEN), Radon (RAD)
Compliance	Cultural Resources (CUL)	Archeological (ARC), Historical (HIS), Native American Graves (NAG)
Compliance	Emergency Planning & Response (EPR)	Air Risk Management (ARM), EPCRA/SARA/EO 12856 (ESE), Facility Response Plan (FRP), RCRA Contingency Plan (RCP), Spill Contingency Plan (SCP), Spill Prevention Plan (SPC)
Compliance	Hazardous Waste (HZW)	Hazardous Material (HMM), General (GEN), Hazardous Waste Generator (HWG), Munitions (MUN), Training (TRA), Treatment/Storage/Disposal (TSD)
Compliance	Installation Restoration (INS)	General (GEN)
Compliance	Natural Resources (NAT)	General (GEN), Multi Land Use Management (MLU)
Compliance	National Environmental Protection Act (NEP)	General (GEN)
Compliance	Noise Pollution (NOI)	General (GEN)
Compliance	Polychlorinated Biphenols (PCB)	General (GEN)
Compliance	Pesticides (PES)	General (GEN)
Compliance	Pollution Prevention (POL)	EO 13814 (EOP), General (GEN), Used Oil Management (OIL), Recycling (REC)
Compliance	Potable Water (POT)	General (GEN)
Compliance	Solid Waste (SOL)	Generation (GEN), Infectious Waste (INF)
Compliance	Storage Tanks (STO)	Above Ground Storage Tank (AST), Underground Storage Tank (UST)
Compliance	Water (WAT)	General (GEN)
Management	Program Management (EPM)	Auditing (ECE), Policy (POL), Training (TNG)

Each category may have one or more subcategories which constitute different areas of focus under the main category. Each question pertaining to a given category is sorted into an appropriate subcategory, resulting in a possible 39 different category/subcategory combinations, known as media areas. Evaluation results were tallied and grouped by media areas for reporting purposes.

3.3.2. Use of the Automated Compliance Evaluation (ACE) software

In 1995 the Marine Corps outsourced the requirement of conducting regular environmental audits to professionals outside the military, as the Marine Corps does not possess the environmental testing equipment or personnel in sufficient quality and/or quantity to conduct these audits. The Marine Corps hired an environmental contractor, Potomac Hudson Engineering, Inc. (PHE), to perform the required environmental audits of all Marine Corps installations. Under the contract, PHE provides a team of professional environmental engineers and scientists to assist HQMC personnel in conducting each environmental audit, evaluating all applicable ECE media areas.

In 1995, PHE developed the Automated Compliance Evaluation software for use in the Marine Corps ECE program. ACE provides a comprehensive platform that maintains inspection question databases, creates installation specific checklists, and records and stores ECE results for all installations. The core of the ACE software is the installation-unique checklist. The inspection checklists are derived from three major sources: Federal, state/local, and DoD/service policy, and are further organized into 39 media areas, the same as shown in Table 4. Depending on locality, the combined size of these checklists currently total between 8,000 and 12,000 questions per installation. While the Federal and DoD/service policy portions are consistent across all installation checklists, the state/local checklist portions vary depending on state and local environmental laws and policies. These checklists are used to determine a facility's compliance with environmental requirements, where all questions are worded such that a "yes" response indicates compliance and a "no" response indicates non-compliance with a given regulation. A representative portion of a checklist is shown in Appendix A. For purposes of this study, the scores that an installation receives in each category are indicative of the installation's level of performance in that area. The compliance level for each installation is represented by the aggregate of all the compliance category scores, while the management level is represented by the management category score.

3.4. Processing Data/ Data Conversion

3.4.1. Use of ECE report data

Upon completion of an ECE, each installation receives a formal report documenting the installation's performance in all applicable media areas and a summary of the installation's strengths and weaknesses. A Statistical Summary Report (SSR), shown in Figure 6, comprises one section of the formal report from the contractor's auditing team to the installation.

Statistical Summary:

Start: 08/11/1997 **End:** 08/22/1997 **Evaluation Id:**

Program	Questions	Yes	NA	NR	No	Pos	FINDING	DISCREPANCY	ISSUE	GENERAL
AIR-ASB	195	35	158	0	2	1	0	2	0	0
AIR-GEN	790	377	405	6	2	0	1	1	0	0
AIR-RAD	3	0	2	0	1	0	0	1	0	0
CUL-ARC	27	3	22	0	2	0	0	1	0	0
CUL-HIS	33	8	24	0	1	0	0	0	0	1
CUL-NAG	37	1	35	0	1	0	0	0	0	1
EPR-ARM	1	1	0	0	0	0	0	0	0	0
EPR-ESE	54	41	13	0	0	0	0	0	0	0
EPR-FRP	304	76	221	3	4	0	0	3	0	1
EPR-RCP	44	23	4	17	0	0	0	0	0	0
EPR-SCP	53	52	0	1	0	0	0	0	0	0
EPR-SPC	102	60	16	13	13	0	8	5	0	0
HZW-HWG	399	133	228	18	20	0	3	19	0	1
HZW-TRA	123	13	106	4	0	0	0	0	0	0
HZW-TSD	1197	184	965	43	5	0	3	5	0	0
INS-GEN	254	237	0	16	1	0	0	1	0	0
NAT-GEN	111	25	63	20	3	0	2	1	0	0
NAT-MLU	121	71	7	39	4	0	4	0	0	0
NEP-GEN	121	42	77	0	2	0	0	1	0	1
NOI-GEN	87	56	31	0	0	0	0	0	0	0
PCB-GEN	257	64	176	17	0	0	0	0	0	0
PES-GEN	362	0	360	0	2	0	0	0	1	2
POL-EOP	29	16	13	0	0	0	0	0	0	0
POL-GEN	9	5	4	0	0	0	0	0	0	0
POL-OIL	280	108	169	0	3	0	3	0	0	0
POL-REC	294	26	267	0	1	1	0	0	1	0
POT-GEN	1715	889	808	9	9	0	1	7	1	0
SOL-GEN	1495	43	1444	3	5	0	4	0	0	1
SOL-INF	173	75	97	0	1	0	0	0	1	0
STO-AST	46	2	43	0	1	0	1	0	0	0
STO-UST	458	263	194	0	1	0	0	0	0	1
WAT-GEN	1373	188	1179	4	2	0	2	2	0	2
TOTALS	10547	3117	7131	213	86	2	32	49	4	11

Figure 6: ECE Statistical Summary Report (SSR). The SSR shows the number of questions asked in a particular ECE, broken out by the program.

The columns of the SSR indicate the responses, while the rows are divided into the different media areas, named by the category-subcategory codes. The numbers in the report represent the count of questions that occurred for a given media area and response combination. Table 5 illustrates the response definitions for each of the column headers in the SSR.

Table 5: SSR Response Definitions. Each type of possible response for a question posed on an ECE is explained, using the same nomenclature for responses as seen on the SSR.

Questions	**Total number of applicable questions derived from all sources**
Yes	Number of questions evaluated that were within compliance with the requirement
NA	Number of questions 'not applicable' to the installation
NR	Number of questions 'not reviewed' by the evaluation team
No	Number of questions evaluated that were not within compliance with the requirement
Pos	Number of questions with superior performance, practice, process noted
Finding	Number of questions with serious departure from requirement which could result in serious adverse response from outside authorities
Discrepancy	Number of questions where a significant discrepancy from requirement existed
Issue	Number of questions where there was an underlying issue which prevented compliance
General	Number of question with a general comment attached to clarify nature of primary response.

The SSR lists the number of applicable questions in each media area, as well as how many questions were in accordance with regulations, denoted by the number of "yes" scores, and how many requirements were not met, denoted by the number of "no" scores. For each question, the evaluation team also has the option to attach amplifying comments to a "yes" or "no" answer. For example, in the case of notably superior performance on a question answered "yes", the team may mark a Positive finding, indicating that the installation went "above and beyond" the minimum requirements of the question. In a similar fashion, questions answered "no", may be declared a Finding, Discrepancy, or an

Issue according to the severity of the gap between the requirement and the observed state of affairs.

The SSR was the main data source for this study. Initially, the number of requirements for each media area was tallied. Then, the performance in each media area was determined by recording the number of questions answered “yes” over the number of questions inspected to arrive at a score for each media area, for each evaluation. The subsequent statistical analyses contained in this study use the management and compliance scores derived from the SSR.

3.4.2 Formatting, Isolating, and Calculating Variables of Interest

The first step in preparing the data for a statistical analysis was to transfer the data into a common spreadsheet program. While the ACE software does produce the pertinent data for analysis within the SSR for each installation, the output file for this report was a Microsoft Document Image, which was incompatible with entry into a statistical analysis software program. Table 6, shows the information for one SSR transferred into a Microsoft Excel spreadsheet.

Table 6: Transformed data for one installation's evaluation. Data was taken from an SSR and input into Microsoft Excel Spreadsheet format; data of interest in this study was highlighted.

Installation	Evaluation Date	Program	Questions	Yes	NA	NR	No	Positive	Finding	Discrepancy	Issue	General
m00004	11/3/2000	AIR-ASB	217	33	178	3	3	1	2	1	0	1
m00004	11/3/2000	AIR-GEN	569	247	300	15	7	0	2	4	1	0
m00004	11/3/2000	AIR-RAD	9	4	5	0	0	0	0	0	0	0
m00004	11/3/2000	CUL-ARC	62	32	17	11	2	0	0	1	0	1
m00004	11/3/2000	CUL-HIS	63	46	11	6	0	0	0	0	0	0
m00004	11/3/2000	CUL-NAG	143	6	3	134	0	0	0	0	0	0
m00004	11/3/2000	EPM-ECE	40	18	2	11	9	0	0	8	1	0
m00004	11/3/2000	EPM-POL	148	93	10	36	9	0	0	9	0	0
m00004	11/3/2000	EPM-TNG	59	8	0	48	3	0	0	3	0	0
m00004	11/3/2000	EPR-ARM	212	147	62	0	2	0	0	1	0	1
m00004	11/3/2000	EPR-ESE	77	34	16	26	1	0	1	0	0	0
m00004	11/3/2000	EPR-FRP	683	77	605	0	1	0	0	0	0	1
m00004	11/3/2000	EPR-GEN	17	9	5	2	1	0	0	0	0	1
m00004	11/3/2000	EPR-RCP	58	37	3	18	0	0	0	0	0	0
m00004	11/3/2000	EPR-SCP	113	80	32	1	0	0	0	0	0	0
m00004	11/3/2000	EPR-SPC	111	81	24	2	4	1	2	1	0	1
m00004	11/3/2000	HZW-GEN	43	43	0	0	0	0	0	0	0	0
m00004	11/3/2000	HZW-HWG	438	245	180	0	13	0	4	6	4	2
m00004	11/3/2000	HZW-MUN	73	19	53	0	1	0	0	0	0	1
m00004	11/3/2000	HZW-TRA	160	80	80	0	0	0	0	0	0	0
m00004	11/3/2000	HZW-TSD	1403	227	1175	0	1	0	0	0	0	1
m00004	11/3/2000	INS-GEN	292	163	127	0	2	1	0	2	0	0
m00004	11/3/2000	NAT-GEN	130	39	85	5	1	1	0	0	1	0
m00004	11/3/2000	NAT-MLU	228	87	103	34	4	0	1	2	1	1
m00004	11/3/2000	NEP-GEN	230	202	15	12	1	0	0	0	0	1
m00004	11/3/2000	NOI-GEN	105	60	38	6	1	1	0	1	0	0
m00004	11/3/2000	PCB-GEN	398	87	239	71	1	0	0	1	0	0
m00004	11/3/2000	PES-GEN	469	131	315	18	5	0	1	4	0	0
m00004	11/3/2000	POL-EOP	91	77	3	6	5	0	0	5	0	1
m00004	11/3/2000	POL-OIL	276	20	252	1	3	0	1	2	0	0
m00004	11/3/2000	POL-REC	138	83	41	10	4	0	0	2	0	2
m00004	11/3/2000	POT-GEN	764	280	443	35	6	0	2	4	0	0
m00004	11/3/2000	SOL-GEN	601	49	546	0	6	0	2	4	0	1
m00004	11/3/2000	SOL-INF	151	113	19	15	4	1	0	5	0	0
m00004	11/3/2000	STO-AST	49	1	45	0	2	0	1	2	0	0
m00004	11/3/2000	STO-UST	344	143	161	33	7	1	1	5	0	1
m00004	11/3/2000	WAT-GEN	397	28	364	1	4	0	1	0	2	1
		Total		3010			92					

Note that since this inspection was conducted in 2000, it includes all compliance categories as well as the management (EPM) category. The first column, marked "Installation," contains the Unit Information Code (UIC) which is specific to each installation, while the second column is marked "Evaluation Date," contains the particular date the audit was conducted. In Table 6, and in subsequent graphics contained in this thesis, the UICs have been changed to preserve installation anonymity. UICs seen in the accompanying graphics are for illustrative purposes only. The following columns are the same as those displayed on the original SSR from ACE, with the columns of interest highlighted. This study excludes the number of questions classified as "NR" – not reviewed, and "NA" – not applicable from the total counts, as those questions were not evaluated by the inspection team. One common reason for questions being classified as NA include an environmental requirement that is applicable in a certain state/local region, but not an issue on the base being evaluated. A question might read: "All underground storage tanks with heat sensitive contents must have temperature gauges", however, a given base may have no underground storage tanks with heat sensitive contents which would result in the question being marked 'NA'. A question might be marked as "NR", when it is one of a series of questions which was not reviewed, because a larger requirement received a "No" response.

The next step was to isolate the data of interest from each installation's SSR. It was necessary to have all pertinent data in spreadsheet format in order to later process the information using statistical software. In terms of answering the research questions, five major types of data were needed from each SSR:

- the Total Compliance score,
- the Total Management score,
- and the three management subcategory scores (Audit Management, Policy Management, and Training Management)

The Total Compliance score was found by adding the total number of questions answered "Yes" or "No" in all 15 compliance categories. The sum of the number of "Yes" answers in all 15 compliance categories was then divided by the total – forming a simple ratio. The Total Management score was found in the same manner as the Total

Compliance score, adding all the management subcategory scores and dividing. Each management subcategory score was also calculated individually for use in the analyses. Table 7 shows the result of consolidating all SSRs on file for one installation and the corresponding data scores of interest. Note that A, B, and C series scores of interest have been calculated for each variable of interest.

Table 7: Score chart for one installation, three evaluations. Total Compliance, Total Management, and the three Management subcategories are isolated from the SSR data.

Installation	Evaluation Date	Time Series	Program	Questions	Yes	No
m00004	**6/6/1997**	**A**	**Total Comp**	**1822**	**1733**	**89**
m00004	**11/3/2000**	**B**	**Total Comp**	**3102**	**3010**	**92**
m00004	11/3/2000	B	EPM-ECE	27	18	9
m00004	11/3/2000	B	EPM-POL	102	93	9
m00004	11/3/2000	B	EPM-TNG	11	8	3
m00004	**11/3/2000**	**B**	**Total EPM**	**140**	**119**	**21**
m00004	**2/19/2003**	**C**	**Total Comp**	**2934**	**2886**	**48**
m00004	2/19/2003	C	EPM-ECE	36	36	0
m00004	2/19/2003	C	EPM-POL	127	127	0
m00004	2/19/2003	C	EPM-TNG	46	44	2
m00004	**2/19/2003**	**C**	**Total EPM**	**209**	**207**	**2**

Note that the first inspection in the series has compliance scores, but no management information, as no management questions were included in the 1997 checklists. In the subsequent evaluations for the same installation, conducted in 2000 and 2003, all three management subcategories were included, and management scores were available for these evaluations. Additionally, a time series code, shown in the column labeled "Time Series," was created for each evaluation to track the date period that the inspection took place. All evaluations conducted between 1995 and 1997 were given an "A" code to denote their date. All "A" evaluations only have total compliance scores available, as management requirements had not yet been mandated during this time period. The second time period, “B,” includes inspections conducted between 1998 and 2001, and the last time period, “C,” includes inspections conducted between 2001 and 2004. Both “B” and “C” series had inspections conducted in 2001, due to the requirement that all active duty installations be evaluated on a triennial basis. At times, as in 2001, the scheduling and execution of the evaluations does not exactly coincide with the calendar year, nor is it required to. In Table 7 “Total Comp” and “Total EPM” are used to represent the Total Compliance and Total Management categories, respectively. In the case of the management subcategories, they are represented by their media area codes, with EPM-ECE for Audit Management, EPM-POL for Policy Management, and EPM-TNG for Training Management.

The next step was to find a way to compare the five key types of data between installations. Because Marine Corps installations are located throughout the United States as well as overseas, no two installations were in the same state/local area with the exact same installation configuration, operations, and assets. Thus, each installation had a different amount of questions in each media area, as well as varying totals in each of the five data types. In order to compare the evaluation results of different installations, and weight each installation’s results equally in a Marine Corps wide analysis, each type of data was converted into a decimal fraction – representative of the level of performance of each installation in each area. Table 8 shows a representative piece of the consolidated chart containing the scores in each of the five areas of interest: Total Compliance, Total Management, Audit Management (ECE), Policy Management (POL), and Training Management (TNG) for each installation, and each evaluation occurrence.

In the rightmost column of Table 8, the score for each variable of interest was calculated and recorded based on the number of "yes" answers for the variable, divided by the total number of questions for that variable.

Table 8: Section of Consolidated Score Chart for Variables of Interest. Data from all installations is consolidated into a single spreadsheet, and decimal fraction scores are calculated and recorded in the rightmost column.

Installation	Evaluation Date	Time Series	Program	Questions	Yes	No	Decimal Fraction Score
m00004	6/6/1997	A	**Total Comp**	**1822**	**1733**	**89**	0.9512
m00004	11/3/2000	B	**Total Comp**	**3102**	**3010**	**92**	0.9703
m00004	11/3/2000	B	Audit Mgmt	27	18	9	0.6667
m00004	11/3/2000	B	Policy Mgmt	102	93	9	0.9118
m00004	11/3/2000	B	Training Mgmt	11	8	3	0.7273
m00004	11/3/2000	B	**Total Mgmt**	**140**	**119**	**21**	0.8500
m00004	2/19/2003	C	**Total Comp**	**2934**	**2886**	**48**	0.9836
m00004	2/19/2003	C	Audit Mgmt	36	36	0	1.0000
m00004	2/19/2003	C	Policy Mgmt	127	127	0	1.0000
m00004	2/19/2003	C	Training Mgmt	46	44	2	0.9565
m00004	2/19/2003	C	**Total EPM**	**209**	**207**	**2**	0.9904
m10099	11/1/1996	A	**Total Comp**	**1535**	**1442**	**93**	0.9394
m10099	4/3/2000	B	**Total Comp**	**3197**	**3096**	**101**	0.9684
m10099	4/3/2000	B	Audit Mgmt	14	11	3	0.7857
m10099	4/3/2000	B	Policy Mgmt	85	77	8	0.9059
m10099	4/3/2000	B	Training Mgmt	28	23	5	0.8214
m10099	4/3/2000	B	**Total Mgmt**	**127**	**111**	**16**	0.8740
m10099	4/28/2003	C	**Total Comp**	**3867**	**3781**	**86**	0.9778
m10099	4/28/2003	C	Audit Mgmt	35	35	0	1.0000
m10099	4/28/2003	C	Policy Mgmt	115	113	2	0.9826
m10099	4/28/2003	C	Training Mgmt	21	19	2	0.9048
m10099	4/28/2003	C	**Total EPM**	**171**	**167**	**4**	0.9766
m70004	10/29/1997	A	**Total Comp**	**1988**	**1889**	**99**	0.9502
m70004	2/10/2000	B	**Total Comp**	**745**	**723**	**22**	0.9705
m70004	2/10/2000	B	Audit Mgmt	17	16	1	0.9412
m70004	2/10/2000	B	Policy Mgmt	90	87	3	0.9667
m70004	2/10/2000	B	Training Mgmt	33	29	4	0.8788
m70004	2/10/2000	B	**Total Mgmt**	**140**	**132**	**8**	0.9429
m70004	10/29/2003	C	**Total Comp**	**1425**	**1417**	**8**	0.9944
m70004	10/29/2003	C	Audit Mgmt	35	35	0	1.0000
m70004	10/29/2003	C	Policy Mgmt	111	109	2	0.9820
m70004	10/29/2003	C	Training Mgmt	55	55	0	1.0000
m70004	10/29/2003	C	**Total EPM**	**201**	**199**	**2**	0.9900

Note that both B and C series evaluations have all five data categories of interest including Total Compliance and Total Management scores, as well as the individual management subcategory scores, Audit Management, Policy Management, and Training Management. For the following research questions, only data from the B and C series evaluations were used as both management and compliance scores were available for these evaluations. At this point the data was input into JMP, version 5.1.2, for further analysis. The JMP program is made by SAS Institute, Inc, a well known statistical analysis firm.

3.5 Data Analysis Methodology

3.5.1 Research Question 1: How are the aggregate Total Management, Audit Management, Policy Management, Training Management, and Total Compliance scores distributed? Furthermore, how are the different types of Management scores distributed when ordered by compliance standing? For the first part, histograms for each type of ECE score were created using JMP statistical analysis software. Common descriptors for each type of data such as the count, minimum, maximum, range, mean, and variance were then calculated. These descriptors were then used to characterize the nature of the sample data. For the second part, the data was ordered into three groups by the magnitude of the compliance score associated with each management score for a given ECE. To do this, the installations were ordered by their total compliance score and separated into the upper, middle, and lower third. The data were divided into thirds because the upper third of the compliance scores best represented “highly compliant” installations to the thesis sponsor. Then, a grouped scatterplot of individual management scores was created for each third of the installations, graphically displaying the data. In examining the shape and placement of the different management scores on a decimal fraction scale from 0.0 to 1.0, it can be ascertained if a management category is different in highly compliant installations as compared to less compliant installations. Finally, a visual comparison of the range and variance of each type of management score was conducted.

3.5.2. Research Question 2: What is the relationship between each management area (Total Management, Audit Management, Policy Management, Training Management) and Total Compliance? The hypothesis states that each area of management is positively correlated with Total Compliance. To answer this question, the data was tested for a positive correlation between each type of Management score and Total Compliance score. This question examines the behavior of two variables, with a respective Management score, x, being the independent or predictor variable, and the Total Compliance score, y, always being the dependent or response variable. Four comparisons were conducted to answer this question:

a. Total Management score (x) versus Total Compliance score (y)
b. Audit Management score (x) versus Total Compliance score (y)
c. Policy Management score (x) versus Total Compliance score (y)
d. Training Management score (x) versus Total Compliance score (y)

The relationship between two variables can be described by using their correlation as a measure. The sample data composition determined the type of statistical analysis that was applied to answer the question. Parametric statistical methods are used if the sample data meets certain assumptions. In the event that the data does not meet the parametric assumptions, a nonparametric analysis can be performed, as nonparametric methods do not require as stringent assumptions as parametric methods. The steps to be followed for the parametric case, involve calculating Pearson's product moment coefficient of correlation through a linear regression, whereas the nonparametric case involves calculating Spearman's rank correlation coefficient (McClave et al., 2001).

A preliminary evaluation of the data showed that parametric assumptions were not met for each of the four cases being examined. All four cases were submitted to and met the required assumptions for the nonparametric approach. Whereas in a parametric analysis the mean of a sample is used to make inferences about the population, in nonparametric statistics the distribution of the sample is used to make inferences about the population. In the nonparametric approach for this type of problem, variables are related in a fashion analogous to linear regression by assigning each measurement within a sample an ordinal rank, relative to the magnitude of all the other measurements within the sample. McClave et al. (2001), described a procedure for calculating and evaluating Spearman's rank correlation coefficient, as detailed below:

1) Rank order all observations within each sample. Ranks are assigned for all measurements of the dependent as well as the independent variables.

2) Calculate Spearman's rank correlation coefficient between the Total Compliance score and the respective Management score for each case, a through d. Through comparison of the differences between the ranks for each pair of measurements, the measure of correlation between the ranks (and thus the variables) can be calculated by using Equation 1 for Spearman's rank correlation coefficient (r_s) (McClave et al., 2001: 921):

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \quad (1)$$

where:

$d_i = u_i - v_i$; the difference in ranks of the ith observations for in the x and y samples
n = number of observations recorded for each sample
u_i = an observation within the x sample
v_i = an observation within the y sample

For purposes of this research question, the ECE scores from a particular installation in a particular year comprise one experimental unit. Two responses for each experimental unit are analyzed; the first response (x sample) is the Total Compliance score, while the second response (y sample) is the respective Management score. The value for r_s will always fall between -1 and +1, with +1 indicating perfect positive correlation and -1 indicating perfect negative correlation. A positive correlation indicates that as the independent variable increases in magnitude, so does the dependent variable, while a negative correlation indicates that the opposite is true. The closer r_s falls to +1 or -1, the greater the correlation between the ranks. Conversely, the nearer r_s is to 0, the less the correlation between variables (McClave et al., 2001).

3) Perform a nonparametric hypothesis test to statistically evaluate the usefulness of the results. First, the type of test statistic used to evaluate the hypothesis was selected. Here, ρ is defined as the population rank correlation coefficient, i.e. the rank correlation coefficient that is calculated from all (x, y) values in the population. For this research question, it was hypothesized that ρ is greater than zero, mathematically indicating that there is a positive linear correlation between a group of Management

scores and Total Compliance scores. In statistical terms this is equivalent to stating that ρ is less than or equal to zero for the null hypothesis (H_0) , while ρ is greater than zero for the alternative hypothesis (H_A) (McClave et al., 2001: 923).

$H_0 : \rho \leq 0$, no population correlation between ranks
$H_A : \rho > 0$, positive population correlation between ranks

4) If the results based on sample data are statistically significant, then the results can be interpreted with respect to the underlying population. The hypotheses were evaluated by comparing the respective alpha values and p-values for each case. The degree of certainty surrounding the conclusion depends on the confidence level selected for use in the test, also known as the alpha level. The hypothesis was tested based on an alpha of 0.05, indicating that the conclusion based on sample data will hold true for the underlying population as a whole 95% of the time in repeated sampling. The p-value method was used to evaluate the hypotheses. The p-value is the probability of obtaining a result as extreme as or more extreme than the actual sample value obtained, given that the null hypothesis is true. The p-value is equivalent to an alpha value which falls on the borderline between accepting and rejecting the null hypothesis. If the p-value is less than or equal to the alpha value, it indicates that there is sufficient evidence to reject the null hypothesis, and the alternative hypothesis is accepted. Conversely if the p-value is greater than the alpha value, then there is there is insufficient evidence to reject the null hypothesis, and the null hypothesis is accepted. So, if the p-value for any test is less than or equal to 0.05, then the results are statistically significant (Rosner, 1995: 198).

3.5.3 Research Question 3: How do Total Management, Audit Management, Policy Management, and Training Management scores compare between earlier (1998-2001) and later (2001-2004) series of evaluations?

The hypothesis states that there was an improvement from the earlier B series to the later C series scores in each Management area. To answer this question, the scores relating to a specific Management area were sorted into B series and C series groups, by installation, then entered into a two way contingency table for analysis. Four comparisons are conducted to answer this question:

a. Total Management scores: B series versus C series
b. Audit Management scores: B series versus C series
c. Policy Management scores: B series versus C series
d. Training Management scores: B series versus C series

A contingency table analysis was used to evaluate this question, because two qualitative factors were being compared: 1) the response on evaluation questions and 2) the time period associated with the evaluation. Also, all the Management score data were in the form of proportions, which lent itself to a contingency table analysis, as compared to other statistical analysis options. Rosner (1995), described a procedure for using a two way contingency table to evaluate binomial proportions, as detailed below:

1) Fit data into the appropriate format for a two-way contingency table analysis. Once the two factors of response and time period were selected for the two way contingency table, Fisher's exact test was selected for use in the analysis. Subsequent sections explain why Fisher's exact approach was selected as the most appropriate approach due to the format of the data and the nature of the hypothesis being tested.

Here, the counts are represented by the answer for each evaluation question in a given classification. The two main factors of response and time period were further divided and all the observed counts were sorted into k classes of possible outcomes. The random variables of interest are the counts or the number of observations that fall into each of the 'k' outcomes (Rosner, 1995). There were four classes, which are the same for each case: 1) Yes, B series, 2) No, B series, 3) Yes, C series, and 4) No, C series. The responses were divided by the evaluation time period (B series or C series), which installation was being evaluated, and what Management area (Total, Audit, Policy, or Training) the question was pertaining to.

2) Create a contingency table from the observed values.

An example contingency table representing one installation's responses for case A is shown in Table 9**.**

Table 9: Example Installation Contingency Table Format. The Response factor and the Time Period factor are entered into a two by two (2 x 2) contingency table for analysis using the Fisher's exact approach and associated test.

Installation 1

		Total Management Response		
		Yes	No	Total
Evaluation Time Period	B series	29	4	33
	C series	33	2	35
	Total	62	6	68

In Table 9, the number in the "Total" column indicates the number of questions that were asked in the indicated Management area, during the ECE that occurred during the given time period, for Installation 1. The counts in the "Yes" and "No" columns represent the number of questions answered “yes” and “no,” respectively for the given Management area during the given ECE. While case a of this question examined the trend for Total Management scores, cases b, c, and d used the same methodology to identify trends for Audit, Policy, and Training Management, respectively.

In selecting the approach to use in analyzing the data, two specific methods were considered: the Mantel-Haenszel approach and the Fisher’s exact approach. The Mantel-Haenszel approach advocated organizing the data into ‘s’ strata, effectively blocking for installation. However, this analysis would only show the trend in Management scores for an individual installation. Since this research question sought to reveal Marine Corps wide trends, the Fisher’s exact test format was seen as the most suitable approach and test for the situation. To use the Fisher’s exact approach, each installation specific two by two (2 x 2) contingency table for a given Management area were combined to create one aggregate table. This was accomplished by adding the counts from each subordinate installation table in each of the four classes of possible outcomes [1) Yes, B series, 2) No, B series, 3) Yes, C series, and 4) No, C series.] While consolidating all installation’s scores into one aggregate table may have obscured trends at individual installations, it was a necessary step to perform the Fisher’s exact test, which requires one two by two contingency table (Higgins, 2004).

3) Evaluate assumptions associated with Fisher’s exact approach to ensure Fisher’s exact test can be performed. The observed data associated with each case of this question met the required assumptions; documentation is provided in the chapter four results section for this research question, section 4.3.

4) Conduct an hypothesis test by comparing the marginal probabilities contained in the contingency table, and statistically evaluate the usefulness of the results. The marginal probabilities associated with a contingency table are found by dividing the count for an individual class, by the total count in the same row or column. Then the marginal probabilities that are found from the observed values are compared to marginal probabilities calculated using a hypergeometric distribution. The difference in these probabilities is then used in the hypothesis test.

The most common hypotheses associated with a two way contingency tables state that variables are independent for the null hypothesis, and the variables are dependent for the alternative hypothesis. This type of hypothesis test is two tailed, and simply determines if there is a *difference* between two factors without any indication as to the direction of the difference (Rosner, 1995). The Mantel-Haenszel hypothesis test is a typical test of independence used with a contingency table analysis that would have effectively confirmed a difference in two factors (Higgins, 2004). The Fisher's exact test is another approach to contingency table analysis, which has an associated one-tailed test, which enables one to discern if proportions associated with one factor are greater than or less than the proportions associated with another factor. The null hypothesis associated with Fisher's exact test is: The event of an observation being in a particular row is independent of that same observation being in a particular column (BBN Corporation, 1996). The Mantel-Haenszel approach and hypothesis test were considered, then discarded, as they would have only confirmed the difference in B series and C series responses for at least one installation. Since this research question and hypothesis needed to determine an improving trend involving an inequality in the alternative hypothesis, Fisher's exact enumeration approach and associated hypothesis test were used.

Fisher's exact test for a 2x2 contingency table is a test of the null hypothesis that the row classification factor and the column classification factor are independent. Fisher's exact test consists of calculating the actual hypergeometric probability of the observed 2x2 contingency table with respect to all other possible expected 2x2 contingency tables with the same column and row totals (BBN Corporation, 1996). The marginal probabilities, in this case p_B and $p_{C,}$, associated with the observed and expected contingency tables were used as the test statistic for the Fisher's exact (hypothesis) test. For purposes of this research question, the hypotheses being tested were:

H_0: $p_B \geq p_C$, response rate (Yes) for B series is greater than equal to the response rate (Yes) for C series
H_A: $p_B < p_C$, response rate (Yes) for B series is less than the response rate (Yes) for C series

where:

p_1 = the probability that a question resulted in a 'Yes' response for a B series evaluation
p_2 = the probability that a question will result in Yes' response for a C series evaluation

Thus the null hypothesis would be true when a respective Management level stayed the same or declined from the B series to the C series, whereas the alternative hypothesis would indicate that the respective Management level improved from the B series to the C series (Rosner, 1995).

5) If the results based on sample data are statistically significant, then the results can be interpreted with respect to the underlying population. The hypotheses were evaluated by comparing the respective alpha values and p-values for each case. Through

the Fisher's exact test, the actual hypergeometric probabilities of the observed 2x2 contingency table were compared with the probabilities of all possible 2x2 contingency tables with the same column and row totals. The sum of these probabilities is the p-value (BBN Corporation, 1996). The degree of certainty surrounding the conclusion depends on the confidence level selected for use in the test, also known as the alpha level. The hypothesis was tested based on an alpha level of 0.05, indicating that the conclusion based on sample data will hold true for the underlying population as a whole 95% of the time. The p-value method was used to evaluate the hypotheses. The p-value is the probability of obtaining a result as extreme as or more extreme than the actual sample value obtained given that the null hypothesis is true (Rosner, 1995). The p-value is equivalent to an alpha value which falls on the borderline between accepting and rejecting the null hypothesis. Here if the sum of probabilities associated with the possible contingency tables (representing the p-value) is less than or equal to the specified alpha level, then the null hypothesis is rejected, and the alternative hypothesis is accepted (BBN Corporation, 1996). Conversely if the p-value is greater than the alpha value, then there is there is insufficient evidence to reject the null hypothesis, and the null hypothesis is accepted. So, if the p-value for any test is less than 0.05, then the results are statistically significant (Rosner, 1995: 198).

3.5.4 Research Question 4: How are the root causes of compliance deficiencies (i.e. Management, Plans & Procedures, Resources, or Training emphasis) grouped when ordered by their compliance standing and when ordered by the time period they occurred in? Each piece of root cause data stems from a unique deficiency on an evaluation, performed at a given installation, at a given point in time (either B series or C series.) To answer this question, the data was divided two ways:

a. by total compliance score achieved on the evaluation, and

b. by the time period (B series or C series) of the evaluation.

After entering the data into a Microsoft Excel Spreadsheet, a bar chart was created to visually display the relative occurrence rates side by side. In both case a and b, the relative incidence rates were observed and examined to identify the most relevant reasons for noncompliance within similar compliance group and within similar time periods.

For case a, all installations with available root cause data were ordered by total compliance score. As in the first research question, the installations were then divided into three groups by their compliance score; upper, middle, and lower thirds. Then the root cause data for each compliance group was summed. In each group, the root cause counts were tallied for each type of root cause. Next, each root cause category was divided by the total root causes recorded for the respective third of installations that fell into that particular compliance group. The result was relative occurrence rates for each type of root cause, for each particular compliance group.

For case b, all evaluations with available root cause data were first separated into a B series group and a C series group. In each B and C series group, the root cause counts were tallied for each type of root cause. Then each root cause category was divided by the total root causes recorded for the respective group of evaluations that fall into the given time period. The result was relative occurrence rates for each type of root cause, for each time period.

IV. Results and Analysis

4.1 Research Question 1

This question examined how ECE scores were distributed in aggregate, and also how each area of Management scores were distributed when grouped by compliance standing. The first part of this research question was to create a histogram in JMP of each of the five variables of interest, which were Total Compliance scores, Total Management scores, Audit Management scores, Policy Management scores, and Training Management scores to determine how the scores of each sample were distributed. The histograms for each sample are as shown in Figures 7 through 11**.** Figure 7 shows that the Total Compliance scores were all above 0.85, indicating that most installations are fulfilling environmental requirements. Most of the scores, approximately 30 are concentrated above 0.95, with a lesser number, just under 10, are between 0.90 and 0.95. Less than four scores were between 0.85 and 0.95.

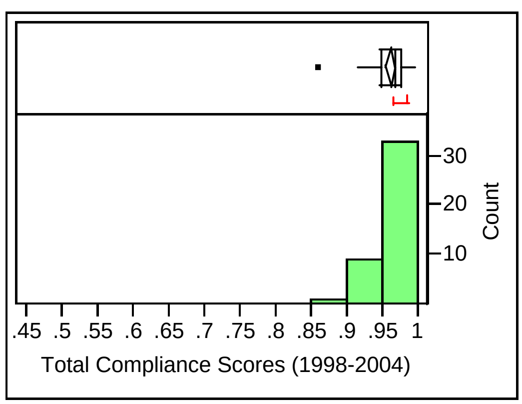


Figure 7: Total Compliance Scores Histogram. All scores are concentrated at the high end of the spectrum, with most scores at 0.90 or above.

Figure 8 shows that the Total Management scores ranged between 0.6 and 1.0, a much larger range than the Total Compliance scores. Nonetheless, most of the scores, approximately 30, are concentrated between 0.85 and 1.0. There are intermittent scores below 0.85, which range down to the 0.6 level.

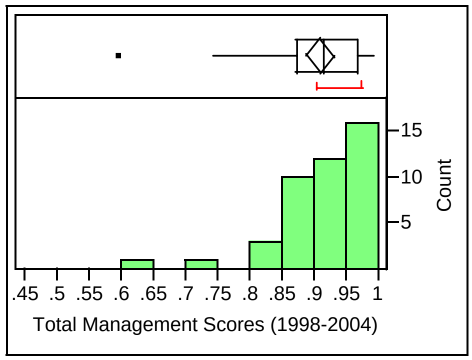


Figure 8: Total Management Scores Histogram. Most Total Management scores are concentrated between 0.85 and 1.0.

Figure 9 shows that the Audit Management scores ranged widely between 0.45 and 1.0. The scores are fairly evenly distributed between 0.70 and 1.0, with approximately five scores in each 0.05 bracket, with a notable spike of 11 in the 0.90-0.95 range. A few scores are scattered below the 0.7 level, with one isolated score in the 0.45-0.50 range.

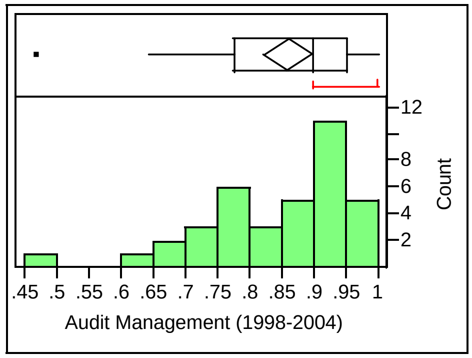


Figure 9: Audit Management Scores Histogram. Most Audit Management scores range between 0.45 and 1.0, the widest range of all variables examined.

Figure 10 shows that the Policy Management scores ranged between 0.55 and 1.0, although there is one isolated score in the 0.55-0.60 interval, and all other scores are above 0.80. In the upper group, most scores are concentrated above 0.90 with relatively few scores falling between 0.80 and 0.90.

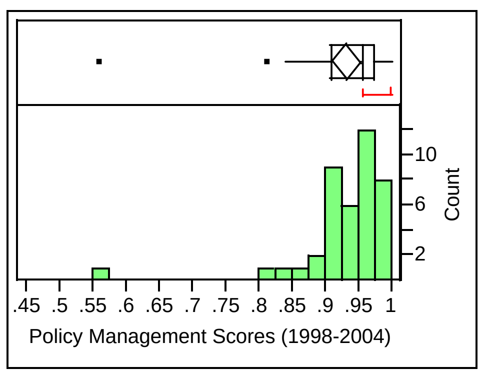


Figure 10: Policy Management Scores Histogram. Policy Management Scores are concentrated above 0.80, with one isolated score in the 0.55 bracket.

Figure 11 shows that the Training Management scores ranged between 0.60 and 1.0. The scores are fairly evenly distributed between 0.80 and 1.0, with approximately five scores in each 0.05 interval, with a notable spike of nine in the 0.90-0.95 range. Only a few scores are scattered below the 0.7 level.

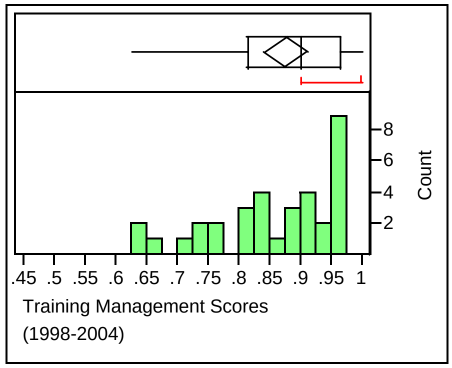


Figure 11: Training Management Scores Histogram. Training Management scores have a broad range from 0.60 to 1.0, however many scores are concentrated in the 0.90 – 0.95 bracket.

Next, the number of data points (count), minimum, maximum, range, mean, and variance of each variable of interest was inventoried. Results are shown in Table 10.

Table 10: Data Descriptors of ECE Score Samples. Most variable had 43 available data points, and mean scores ranged between 0.861 and 0.963.

Variable	# of data points	Minimum	Maximum	Range	Mean	Variance
Total Compliance Scores	43	0.861	0.994	0.133	0.963	0.023
Total Management Scores	43	0.600	0.991	0.391	0.911	0.073
Audit Management Scores	43	0.471	1.000	0.529	0.861	0.119
Policy Management Scores	43	0.563	1.000	0.437	0.934	0.071
Training Management Scores	40	0.600	1.000	0.400	0.878	0.107

Total Compliance had 43 data points, ranging from 0.861 to 0.994. Although Total Compliance scores from the A series evaluations which took place from 1995 to 1997 were available, they were not included in this thesis effort. Only Total Compliance scores from the B and C series evaluations were used, as the B and C series evaluations also inspected management categories and had corresponding management scores. Total Compliance scores had the lowest variance of 0.023 of all the categories that were examined.

All management scores came from B and C series evaluations which occurred between 1998 and 2004. The Total Management scores averaged at 0.911 with a variance of 0.073. The individual management categories means varied from the highest of Policy Management at 0.934, and Training Management and Audit Management somewhat lower with 0.878 and 0.861, respectively. Whereas the Total Compliance scores only had a range of 0.131, all the management scores had ranges three times as large, from 0.4 to 0.5 in general. This may indicate that while all installations are fairly consistent in their compliance levels, and the majority of installations are following management requirements, some of the installations with significantly lower management scores may not be aware of certain management requirements.

While most areas tallied 43 data points, the Training Management category only had 40 valid data points. In Training Management, there were three occasions where standard evaluation policy was not followed, resulting in three invalid scores. These three data points were not included in the Training Management score sample, and only 40 data points were used in subsequent analyses. Since Training Management is one of the subcategories that are combined with Audit Management and Policy Management, to determine Total Management, further adjustments were made. Originally each management category had 43 data points available. The Total Management score is usually found by summing the number of “yes” answers over the total number of “yes” plus number of "no" questions from the three management subcategories. For the installations and evaluation dates with invalid Training Management scores, the Total Management scores were represented by combining the two remaining management subcategory scores.

The second part of this research question evaluated management scores by sorting the scores into an upper, middle, and lower group by compliance. Each management score was plotted on to a scatterplot as shown in **Figure 12.**

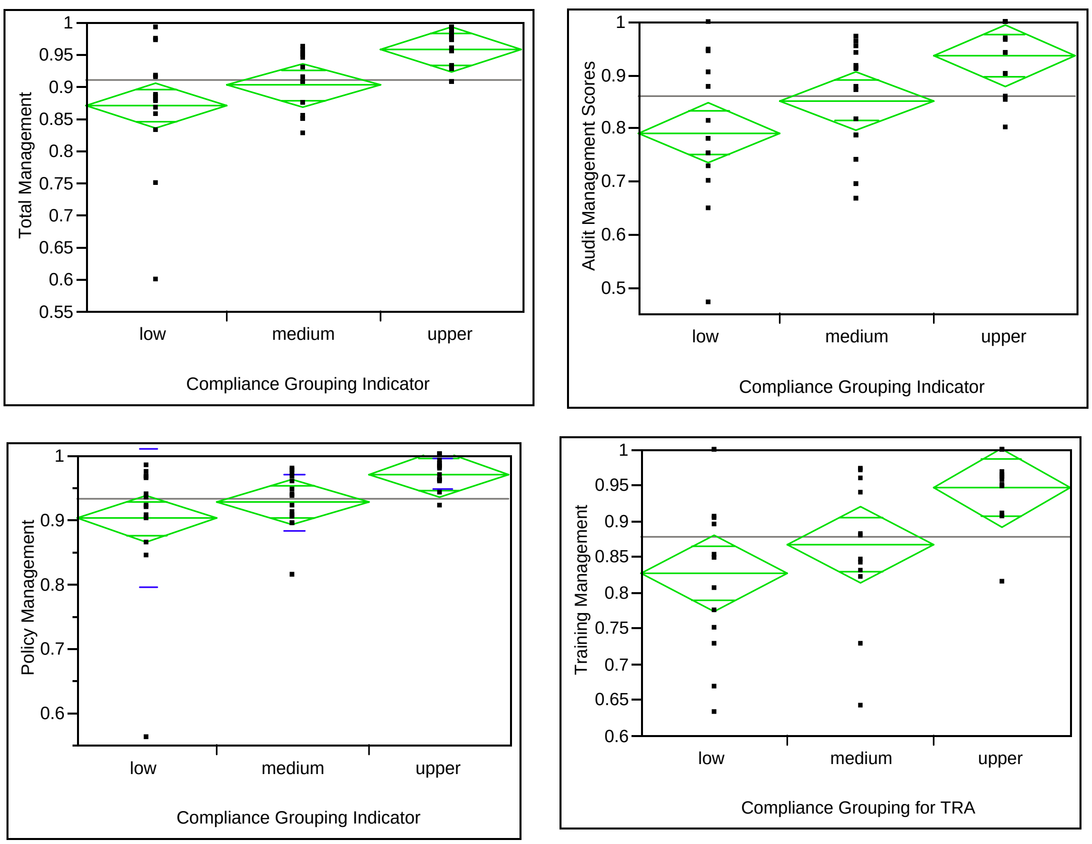


Figure 12: Four Scatterplots of management scores, grouped by compliance standing. In each scatterplot the upper compliance bracket has a definite concentration of higher management scores and while the lower compliance bracket has more lower management scores than the other brackets.

In the scatterplots, each score is represented by one dot. The column where the dot appears depends on which category (low, medium, or upper) the corresponding Total Compliance score was for that installation and evaluation date. The management scores associated with the upper third of compliance scores appear in the rightmost column in each case. Furthermore, the diamond superimposed on the values indicates a 95% confidence interval on the scores in each grouping (upper, middle, lower), while the centerline of the diamond marks the mean score in each grouping. By comparing the regions covered by the diamond, overlaps between groupings initially indicate that the management score distributions are similar between the two groupings being compared. Conversely, if the confidence intervals do not overlap, then the management score distributions are thought to be separate and distinct. In all areas of management, the values of management scores are generally higher for the upper third of compliance installations as compared to the lower third of compliant installations. The difference of management scores for the middle third of compliant installation is less distinct and not statistically distinguishable from either the upper or the lower third. This is shown by confidence intervals between middle to upper and middle to lower overlapping significantly in each type of management examined. This examination suggests that in general, highly compliant installations have higher management scores, regardless of the type, and also lower compliant installations seem to have lower management scores in general.

4.2 Research Question 2:

This question aimed to reveal the relationship between several Management areas when compared with Total Compliance. To answer this question, the data was examined for a positive correlation between each type of Management score and Total Compliance score for all Marine Corps installations over the past eight years. The behavior of two variables was characterized in four different cases, with a respective Management score being, x, the independent or predictor variable, and Total Compliance score always being y, the dependent or response variable. The four comparisons that comprised cases a through d are listed below:

a. Total Management score (x) versus Total Compliance score (y)
b. Audit Management score (x) versus Total Compliance score (y)
c. Policy Management score (x) versus Total Compliance score (y)
d. Training Management score (x) versus Total Compliance score (y)

First, the assumptions for the parametric approach were tested, with the goal of creating a probabilistic model from a linear regression. In all four cases the required assumptions were *not* met, particularly with respect to the third assumption, which requires ε, the random error, to be normally distributed. Discussion and documentation of the parametric assumption tests, including the results for each case are shown in **Appendix B: Evaluation of Parametric Assumption Tests for Research Question 2** (McClave et al., 2001: 473). Since the required assumptions for the parametric approach were not met, the data were subjected to assumptions associated with the nonparametric approach. The two assumptions associated with Spearman's nonparametric test for rank correlation are:

1) The sample of experimental units on which the two variables are measured is randomly selected.

2) The probability distribution of the two variables is continuous.

Since all cases of the sample data met both nonparametric assumptions, Spearman's test was then used to evaluate the relationship between the two variables by rank correlation (McClave et al., 2001: 925).

Following the four methodology steps outlined previously, all sample values were rank ordered through the use of JMP statistical software. Then, Spearman's rank correlation coefficient, r_s , was calculated in each case. Next, using the p-value method for hypothesis testing, a p-value indicating the level of significance of the sample data was calculated for each case. Table 11 shows the Spearman's rank correlation coefficient r_s for each case, the applicable number of sample observations (n), the p-value found in the hypothesis test, and the corresponding significance level. An alpha level (α) of 0.05 was used in each case.

Table 11: Nonparametric Results for Research Question 2. Total Management had the highest correlation coefficient at 0.4885. All Management areas were found to be positively correlated with Total Compliance to a significant degree.

	r_s	n	p value	α	Significance level
Total Management vs. Total Compliance	0.4885	43	0.0009	0.05	Very highly significant
Audit Management vs. Total Compliance	0.4607	43	0.0019	0.05	significant
Policy Management vs. Total Compliance	0.4779	43	0.0012	0.05	significant
Training Management vs. Total Compliance	0.3190	40	0.0371	0.05	significant

Recalling that the value for r_s always fall between -1 and +1, with +1 indicating perfect positive correlation and -1 indicating perfect negative correlation, it was seen that each Management area was positively correlated with total compliance score as each r_s was a positive value. Although the values were not close enough to 1 to indicate a strong correlation, they are still sufficiently greater than 0 to indicate a moderate level of correlation. The results of the hypothesis testing lend a degree of confidence and certainty to the findings. The statistical significance of the data was evaluated by the following hypothesis test:

H_0 : $\rho=0$, no population correlation between ranks
H_A : $\rho>0$, positive population correlation between ranks

In each case the p-value is less than the alpha value, indicating that there is sufficient evidence to reject the null hypothesis, that there is no population correlation between ranks. Since hypothesis testing is based on a binary approach, if the null hypothesis is rejected, it promotes the alternative hypothesis that a positive correlation between the ranks does exist. The p-values found in each case were recorded, as shown in Table 11, and judged based on criteria set forth by Rosner (1995: 200) which are displayed in Figure 13.

Figure 13: Guidelines for Judging the Significance of a p-value (Rosner, 1995: 200). The smaller the p-value of a hypothesis test is, the more significant the results are.

If $.01 \leq p < .05$, then the results are *significant.*
If $.001 \leq p < .01$, then the results are *highly significant*.
If $p < .001$, then the results are *very highly significant*.
If $p > .05$, then the results are considered *not statistically significant*
However, if $.05 \leq p < .10$, then the trend toward statistical significance is sometimes noted.

Generally speaking, the smaller the p-value, the greater the statistical significance of the finding. In other words, the less probability exists that the sample data is not indicative of the nature of the underlying population. As defined by Rosner (1995:200) the significance level of the finding for each case was also included in Table 11. It was seen that while each of the Management area was positively correlated with total compliance to a significant degree, Total Management is positively correlated with total compliance to a very highly significant degree, with a p-value of 0.0009. This indicates that since the sample results indicated a moderate positive correlation between Total Management and Total Compliance, there is a strong chance that higher compliant installations are associated with better environmental management practices. P-values of 0.0012 and 0.0019, for Audit Management and Policy Management, also indicate that there is significant statistical evidence that the moderate positive correlations seen in the sample data can be extended to the larger population. So, better audit management and policy management of environmental matter are also associated with higher compliance levels. Training Management had a slightly greater p-value of 0.0371, and also a slightly lower correlation coefficient of 0.319 as opposed to higher levels near 0.47 for Total Management, Audit Management, and Policy Management. This could indicate that while there was significant statistical evidence that better Training Management practices are associated with higher compliance levels, the positive relationship was not as strong as in the case of Total Management, Audit Management, and Policy Management.

4.3 Research Question 3

This question examined the trend in Total Management, Audit Management, Policy Management, and Training Management scores between earlier and later evaluation series, with the hypothesis that scores in each area improved over time. To answer this question, the data was submitted for a contingency table analysis with the aid of JMP statistical software. The data was evaluated through a one-tailed Fisher's exact hypothesis test. The rows of the contingency tables represented the evaluation time series factor (B series or C series), while the columns of the contingency tables represented the nature of the response factor (Yes or No), where the counts were the number of answers occurring in one of four discrete outcomes, defined by the possible factor combinations. Four cases of this question were examined, as illustrated below:

a. Total Management scores: B series versus C series
b. Audit Management scores: B series versus C series
c. Policy Management scores: B series versus C series
d. Training Management scores: B series versus C series

The first two steps involved fitting data into the appropriate format for a contingency table analysis, and creating a contingency table. Once the sample data was entered for each installation, JMP statistical software was used to combine 18 installation specific contingency tables to create one aggregate contingency table of all the counts associated with a given Management area. The contingency tables containing the counts used in the analyses for each case a through d, are shown in Table 12.

Table 12: Aggregate Contingency Tables. Contingency tables including count data for each case, a through d are provided.

a. Total Management

		Response		
		No	Yes	Total
Time Series	B series	300	2452	2752
	C series	170	3413	3583
	Total	470	5865	6335

b. Audit Management

		Response		
		No	Yes	Total
Time Series	B series	83	348	431
	C series	39	572	611
	Total	122	920	1042

c. Policy Management

		Response		
		No	Yes	Total
Time Series	B series	81	463	544
	C series	58	778	836
	Total	139	1241	1380

d. Training Management

		Response		
		No	Yes	Total
Time Series	B series	136	1641	1777
	C series	73	2063	2136
	Total	209	3704	3913

The third step involved evaluating the assumptions required for Fisher's exact test. For Fisher's exact test, it was assumed that the total number of data values in the 2x2 contingency table was fixed, by virtue of both the row marginal totals and the column marginal totals being fixed (BBN Corporation, 1996). The assumptions are listed and explained below:

Assumption 1: The data satisfies properties of a multinomial experiment. This assumption was satisfied by using a random sample of Management scores at random times from the population of interest (all Marine Corps installations at all points in time). The evaluations were conducted at different points in time at different installations to provide response data for this analysis. This infers that each observation has the same probability of being classified into the ith row and the jth column as any other observation.

Assumption 2: Each object is classified into one and only one category of the row variable, and into one and only one category of the column variable. Each cell of the contingency table was arrived at by inserting raw data from ECEs. This assumption was satisfied because each ECE was independently conducted, and each question response provided a count for one cell in the contingency table (BBN Corporation, 1996).

Since the assumptions were satisfied, the fourth step of hypothesis testing using a one tailed Fisher's exact test was conducted. The stated hypothesis was that there was an improvement in the scores of each Management area from the earlier B series to the later C series evaluations. The statistical significance of the data was evaluated by the following hypothesis test:

H_0: $p_B \geq p_C$, response rate (Yes) for B series is greater than or equal to the response rate (Yes) for C series

H_A: $p_B < p_C$, response rate (Yes) for B series is less than the response rate (Yes) for C series

The p-value approach was used to evaluate the hypothesis. In all four cases, the upper tail (right) p-value was less than 0.0001, yielding a very highly significant determination in each case. This indicates that in each case the p-value was less than the alpha value, and there was sufficient evidence to reject the null hypothesis. Since hypothesis testing is based on a binary approach, and the null hypothesis was rejected, there was sufficient evidence to support the alternative hypothesis that the C series scores are greater than the B series scores in each case at the 0.05 significance level. These results showed that the Management level in each area tested (Total, Audit, Policy, and Training) had improved as a whole between the two time series. Due to the nature of the test, it is only possible to determine that each area improved, but not the magnitude of improvement. These results suggest that the ECE program and its associated feedback mechanisms are working well in the Management areas. It appears that environmental professionals are learning from their past results and improving the quality of Management in each available area.

4.4 Research Question 4: This question examined how the root causes of compliance deficiencies (i.e. Management, Plans & Procedures, Resources, or Training emphasis) were grouped when ordered by compliance group and when ordered by time period. To answer this question, in each case a bar chart was created from entering the pertinent data into Microsoft Excel. The relative occurrence rates were calculated and examined to identify the reason behind most compliance deficiencies in both cases.

For case a, the relative incidence rates for each type of root cause, for each particular compliance group are shown in Figure 14**.** The relative incidences are reflected in the height of the bar associated with each compliance group. The leftmost bar represents the lowest compliance group, the middle bar represents the middle compliance group, while the rightmost bar represents the highest compliance group for each type of root cause.

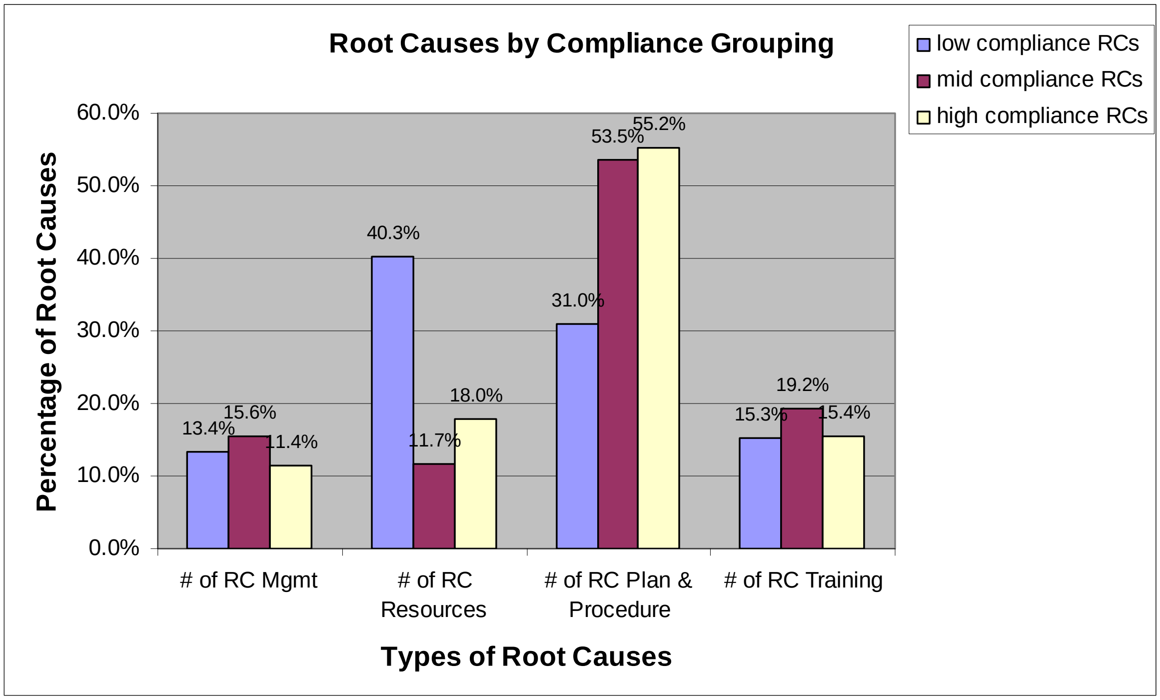


Figure 14: Root Cause Rates when Grouped by Compliance Group. The relative incidence rate is displayed on the y axis and indicated by the height of the bar for each type of root cause on the x axis.

It was seen that in the lowest compliance group, Resources was responsible for 40.3% of the deficiencies. Plans & Procedures was a close second with 31.0%, and both Training and Management were responsible for less deficiencies with relative incidence rates of 15.3% and 13.4%, respectively. The middle and highly compliant groups had similar distribution of the root causes, with Plans & Procedures responsible for more than half of the deficiencies in both compliance groups. The relative incidence rates of the remaining root causes in the middle and highly compliant groups were fairly evenly distributed between 10%-20% in each group. This suggested that low compliance bases had more trouble with attaining compliance due to a lack of Resources, whereas middle and high compliance bases had Resources taken care of, and most compliance problems stemmed from lack of adequate Plans & Procedures.

For case b, the relative occurrence rate for each type of root cause for each time period is shown in Figure 15. In this case, the leftmost bar represents the relative incidences associated with the B series group, whereas the rightmost bar represents the relative incidences of the C series group for each type of root cause.

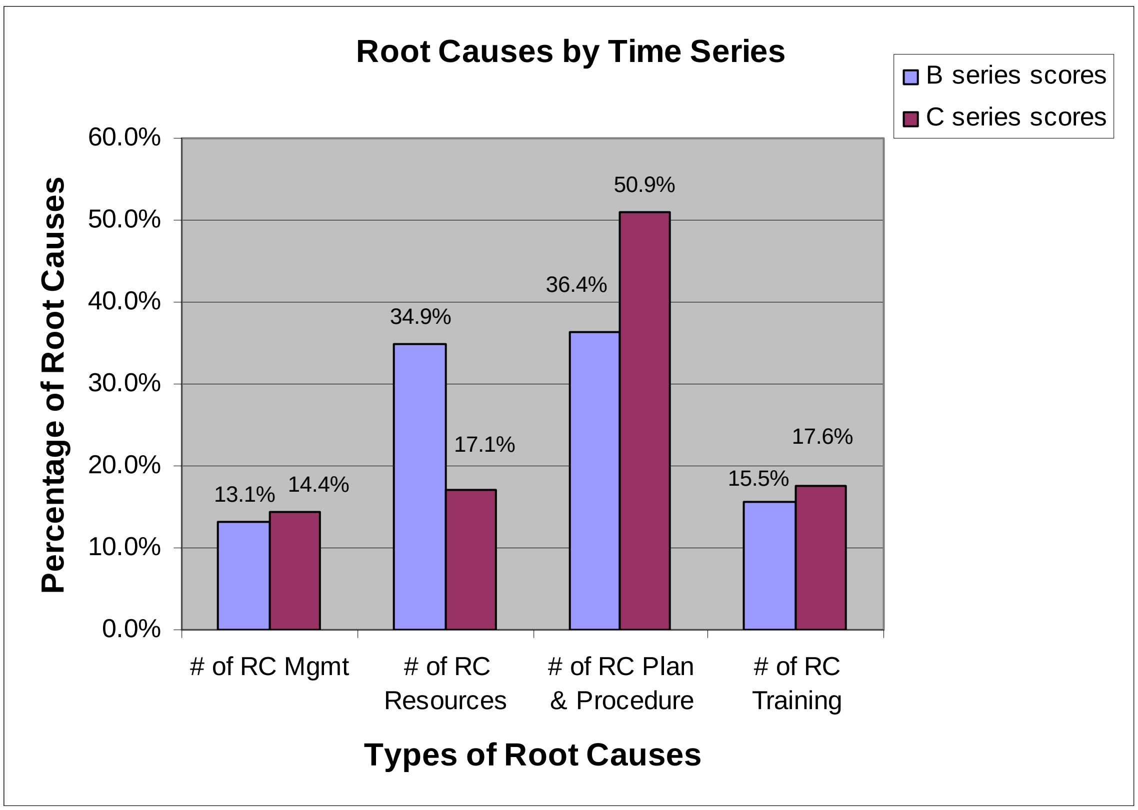


Figure 15: Root Cause Rates when Grouped by Time Series. The relative incidence rate is displayed on the y axis and indicated by the height of the bar for each type of root cause on the x axis.

It was seen that for the earlier B time series, both Plans & Procedures and Resources had the highest percentages of root causes with 36.4% and 34.9%, respectively. After that both Training and Management had much lower relative incidence rates, with 15.5% and 13.1%, less than half of the two most prevalent root causes in the same time series. While the relative rate of Resource root causes decreased from 34.9% to 17.1% the Plans and Procedures increased significantly from 36.4% to 50.9% from the B series to C series. Within the later C time series, Plans & Procedures were responsible for over half of the deficiencies at 50.9%, while the three remaining root causes all occurred about one third as frequently. The remaining root causes of Training, Resources, and Management only varied from 17.6% to 14.4%. This suggests that in earlier years that installations had greater problems attaining compliance from the lack of Resources, but in later years as Resources became less of a problem, Plans & Procedures became more prevalent in deficiencies.

In both groupings displayed in Figures 14 and 15, the prevalence of root causes due to Management and Training tend to be fairly constant between highly, middle, and lowly compliant installations, as well as between earlier and later time series. The root causes due to Resources and the root causes due to Plans and Procedures tend to have wider variations between different compliance postures as well as time series. This may indicate that installations receiving lower compliance scores and in the B time series have faced restrictions on Resources in terms of manpower or funding which prevented them from reaching higher levels of compliance. Perhaps middle and highly compliant installations, as well as in the later C time series in general, installations had done more to identify Resource needs to HQMC, and deficiencies due to Resource problems had been solved. As the amount of deficiencies due to Resources become relatively less, the amount of deficiencies for Plans & Procedures became relatively more. Perhaps another reason for the shift to Plans & Procedures specifically rather than a shifting to Training or Management is the impact of U.S. environmental compliance requirements which are increasingly focusing on preventative procedures, as opposed to just measuring the amount of pollution present.

V. Conclusions

5.1. Overview of Research

This thesis sought to identify the practical connection between environmental management and environmental compliance through analysis of Marine Corps environmental audit (ECE) results. In chapter one the motivation behind the research was explained. The Marine Corps has continued to strived to attain and maintain higher levels of environmental compliance and performance beyond the minimum standards required by environmental laws. As the Marine Corps continues to achieve higher levels of compliance, it is protected from the adverse effects of noncompliance such as land use restrictions, external influence on installation operations, possible civil lawsuits, as well as other penalties and fines that may be assessed by a regulator. Clearly, the Marine Corps has a compelling reason to identify the most relevant areas of environmental management to help assure high levels of compliance.

In chapter two, a literature review was conducted to identify existing links between environmental management and environmental compliance as identified by other researchers. The evolution of contemporary environmental compliance and performance as well as organizational motivators for environmental goals was examined. Next, different types of environmental management approaches were detailed ranging from informal environmental management programs to more formal environmental management systems (EMSs) to EMSs attaining certification under the ISO 14001 standard. Specific environmental management requirements which apply to Federal agencies, particularly the DoD, DoN, and Marine Corps were also covered. The last part of the literature review identified successful environmental management principles including management commitment, employee awareness and comprehension, administrative actions, a systems approach, and integration of environmental affairs into operation, as key elements linked to high levels of environmental compliance.

Chapter three explained the methodology and chapter four addresses the results for the four specific research questions associated with this thesis. The data used in the analysis came from ECEs covering the past eight years, from 1997 to 2004, from active duty installations across the Marine Corps. The ECEs contained questions based off of environmental compliance regulations derived from local, state, and Federal sources, as well as environmental management policy requirements derived from DoD, DoN, and the Marine Corps. Scores associated with Total Compliance, Total Management, Audit Management, Policy Management, and Training Management were calculated for each ECE in decimal fraction form to allow easy comparision between installations which had a different number of requirements in each area. A combination of graphical techniques including histograms, scatterplots, and bar charts were used to answer the first and fourth research questions about the basic nature and distribution of the score data when grouped by compliance standing and when grouped by time series. More intense statistical techniques including the calculation of Spearmann's rank correlation coefficient and the creation of contingency tables were used to test hypotheses concerning the correlation between management areas and compliance and to test the trend between earlier B series and later ECE scores for all of the management areas. The next section summarizes the results contained in chapter four.

5.2. Summary of Results

From the first research question which examined all the pertinent ECE scores, it was seen that Total Compliance scores are high across all Marine Corps installations, with an average of 0.963. Average Management scores were also high, ranging between 0.861 to a high of 0.934, with Policy Management having the highest average. Overall the Marine Corps is complying with environmental regulations and meeting environmental policy requirements. The intial scatterplots for each Management area in research question one also showed that when Management scores were grouped by compliance bracket (upper, middle, and lower thirds), that high Management scores occurred most often when an installation was highly compliant and lower Management scores also occurred when an installation was in the lowest compliance bracket. While there did not seem to be a significant difference between the upper and middle bracket or the middle and lower bracket, there was a significant difference between the upper and lower bracket as indicated by the confidence intervals superimposed on the scatterplots. This lended credence to the idea that high levels of Mangement in each area were positively correlated with high levels of compliance.

In the second research question, the correlation between Total Compliance and each Management area was measured and tested. While Spearmann's rank correlation coefficient varied from between 0.46 to 0.49 for Total Management, Policy Management, and Audit Management, Training Management had a somewhat lower correlation coefficient with 0.32. Each coefficient was found to be significant, indicating that each area of Management was positively correlated with Total Compliance to a moderate degree. This result was consistent with numerous other studies mentioned in the literature review which also stated that environmental management is positively correlated with high levels of environmental compliance (Melnyk et al., 2003; Annadale et al., 2004).

The third research question tested whether Management scores across the Marine Corps had improved over time between the earlier B series of ECE inspections which occurred from 1997-2001 and the subsequent C series of ECE inspections which occurred from 2001-2004. After creating a two way contingency table for each Management area and aggregating each installations values into one table, the contingency tables were evaluated using Fisher's exact test. In each case, it was found that the response rate, or proportion of "yes" answers received during B series ECE's was less than the response rate received during C series ECE's for each area of Management to a very highly significant level. This indicates that Audit Management, Policy Management, Training Management, and Total Management levels have improved over time in the Marine Corps with a large degree of certainty.

The final research question analyzed the relative occurence rate of root causes associated with compliance deficiencies (no responses received during an ECE). When grouped by compliance bracket, the most prevalent root cause in lower compliance installation was overwhelmingly Resources, responsible for 40.3% of compliance deficiencies. In both the middle and higher compliance bracket, Plans & Procedures were responsible for most of the deficiencies at 53.5% and 55.2%, respectively. For all compliance brackets, the Management and Training root causes remained below 20.0%, indicating that they were not usually the largest players in a noncompliance. When grouped by time series a similar pattern occurred, as in the B time series, Resources was the most prevalent root cause with 34.9%, and in the C time series, Plans & Procedures was the most prevalent root cause with 50.9%. Again, the Management and Training root causes remained below 20% in both cases. This indicated that in the lowest compliance bracket, and in the earlier time series that Resources were the chief root cause associated with noncompliance. In the middle and highest compliance brackets as well as the later time series, Plans & Procedures was identified as the chief root cause associated with noncompliance.

5.3. Limitations

This research was limited by the nature of the data as well as the type of data that was collected. In the process of arriving at the scores associated with the five variables of interest (Total Compliance, Total Management, Audit Management, Policy Management, and Training Management) scores associated with varying numbers of subcategories were combined. By combining this data, some of the details associated with the smaller data elements may have been lost in the aggregation. Additionally, since each installation was subject to a different group of requirements, all scores were normalized through a decimal fraction process. Using decimal fractions put each ECE score on equal footing and allowed the relative level of the variables to be compared in an equitable fashion, however, again, the magnitudes associated with the scores were "lost" through this normalization process. The scores for this thesis were calculated by comparing the number of requirements that were fulfilled (with "yes" responses to an ECE question) to the number of requirements that were not fulfilled, receiving a "no" response. While the magnitude and severity of a noncompliant area may have varied between questions, all negative evaluation responses were counted equally in terms of the management and compliance scores.

The data and associated scores collected and calculated from the ECEs was thought to be generally indicative of the level of each Management area as well as the Total Compliance level of the installation being inspected. However, the ECEs and consequently this thesis did not have the ability to take into account what effect fluctuating funding levels may have had on the management and compliance scores and subsequent results, except in the case of the fourth research question, which did include looking at "Resources" as a root cause of noncompliance. Finally, because the data was collected from existing sources and not collected in the construct of a designed experiment, results are used to indicate the trends over time and relationships between environmental management and environmental compliance, but cannot be used to show causality between the two areas.

5.4. Recommendations

This research comes at a very exciting time for the Marine Corps, as the Marine Corps is under the requirement, as are all the other military services, to implement an EMS in every major command by December 31, 2005 as per Executive Order 13148. Although the Executive Order requires organizations to follow an EMS framework similar to that endorsed by the ISO through its 14001 standard, the 14001 standard was theory based. This thesis offers some practical evidence for how environmental management is related to environmental compliance. By taking note of these associations the Marine Corps can focus on and commit more resources to the most pertinent elements of management which promote high levels of compliance and performance. As seen through the research and results management was positively correlated with compliance. This supports the idea that the environmental management policies which have been endorsed by the DoD, DoN, and Marine Corps form appropriate and useful guidance on successfully attaining and maintaining high levels of environmental compliance aboard Marine Corps installations.

Environmental Management in the Marine Corps has improved over the past eight years, therefore, the existing ECE audit program which contains accountability and feedback procedures for management deficiencies and omission is on the right track; promoting the principle of continual improvement in both management and compliance areas. In terms of the root causes of noncompliance, it was clearly seen that Resources were the primary root cause of compliance deficiencies in the earlier ECE series and the lowest compliance bracket. This speaks to the importance of adequate resources in terms of funding and personnel in creating an environment where installations can successfully attain and maintain compliance. The Marine Corps already has a system to identify, prioritize and record environmental budgeting requests, and the aforementioned information suggests that an orderly process for identifying and addressing the root causes of deficiencies has been useful in improving the level of compliance of an installation.

As the Marine Corps fulfills the requirement to implement EMSs at all major installations, certainly the management requirements contained in the ECPM, MCO P5090.2A should be updated to reflect expectations associated with a formal EMS. Correspondingly, the new management requirements should be translated into new inspection questions to be included on future ECEs to ensure that installation EMSs are running properly. This could be a great tool to pinpoint trouble areas during the implementation of EMS throughout the ‘growing pains’ stages. Another interesting thought would be to more closely align the choices of Root Causes to the sections of an EMS, namely, Policy, Planing, Implementation and Operation, Checking and Corrective Action, and Management Review. Theoretically, if an EMS is correctly executed it will promote high levels of performance beyond the minimum levels of compliance required by law through a continual improvement process. If many Root Causes were due to a certain EMS area, environmental managers could more quickly identify the processes which needed attention to resolve deficiencies, and ensure future deficiencies did not occur for the same reason.

5.5. Areas for Future Research

While this thesis offers some insights into the relationship between environmental management and environmental compliance aboard military installations, other studies could better define the connection between the two factors. An obvious extension of this research would be to conduct a similar investigation using another service, or a combination of services to further verify the results found in this thesis. It would also be desirable to complete a similar study in private industry, however, it is unlikely that a private organization would open its environmental data banks to reveal environmental audit results to the public for such a study. Further research could also point to links between the financial aspects of environmental management, and seek to link funding and personnel levels to the strength of an environmental management system or program.

This research would be useful as environmental decisions and issues are quantified in terms of metrics and costing structures, it will be increasingly easy to integrate these decisions and issues into the larger organizational management mainstream.

It would be interesting to attempt to create a systems dynamics model which included funding and personnel elements as well as different types of management influences and compliance and performance goals to better understand the interaction between these key elements at work in an organization in general. Finally, it would be beneficial for a similar study relating environmental management and environmental compliance to be conducted ten years in the future, a point in time where EMS should be firmly entrenched not only in an installation's environmental staff, but hopefully also in Marine Corps command culture. The subsequent study could examine whether the changes made by the move to EMS have been beneficial in raising the overall level of compliance and performance in the Marine Corps over time, and also verify which areas of EMS have been most effective in promoting high levels of compliance. Making the report outputs of the ACE software system compatible with a common spreadsheet program such as Microsoft Excel would aid in future analyses of ECE data.

5.6. Closing Comments

Environmental protection and preservation have been increasing concerns over the past 30 years in both the public and private arenas. The Federal government has encouraged its agencies to use responsible environmental management practices to promote high levels of compliance and conservation to provide a good example to organizations in the public sector. The private sector is increasingly identifying environmental efficiency as a way to obtain a competitive advantage in the marketplace. All organizations have been faced with increasing environmental legal requirements. In light of these factors, improving environmental compliance and performance through environmental management will continue to be an area of focus for the foreseeable future. Hopefully, this research and the research of others, will continue to better define how proper environmental management practices can positively promote the protection and preservation of the environment for future generations and species.

Appendix A: Representative Portion of an ECE checklist

This appendix contains portions of an ECE checklist to illustrate what types of questions are being asked during an ECE. The page below shows Audit Management questions, as indicated by the 'EPM-ECE' code in the upper right corner, under the 'Program' listing. The 'Sequence#' is an internal numbering mechanism associated with the ACE software which creates the installation specific checklist. For each Question listed, the associated Regulation where the requirement came from is also listed. The evaluator's response can be marked in the rightmost column.

Master Checklist - CA SBA 04A /CA 04A/MCO 03A /FED 03A

Effective Date: 07/01/1998

Program	Sequence#	Regulations	
EPM-ECE			
	M-04000-00000	MCO P5090.2A Chapter 4	
Question:	ENVIRONMENTAL COMPLIANCE EVALUATION PROGRAM		*Response*
	M-04020-00000	MCO 4104.2	
Question:	Does the installation prepare and submit to CMC(LF) a Plan of Action and Milestones (POA&M) based on the draft ECE report?		*Response*
	M-04025-00000	MCO 4104.3.	
Question:	Does the installation maintain and use ACE to track both HQMC-sponsored ECEs and the installation Self-Audit Program?		*Response*
	M-04080-00000	MCO P5090.2A 4200.8	
Question:	Conduct of Benchmark ECEs		*Response*
	M-04090-00000	MCO 4200.8(a)	
Question:	Did the installation complete a Pre-ECE Questionnaire and a Point of Contact (POC)/Availability list as requested in the installation notification letter?		*Response*
	M-04120-00000	MCO 4200.8(b)	
Question:	Do the installation POC's develop and coordinate a list of suggested sites and a schedule for the visit?		*Response*
	M-04125-00000	MCO P5090.2A 4200.9(b)	
Question:	Plan of Action and Milestones (POA&M)		*Response*
	M-04129-00000	MCO 4302.4	
Question:	Does the installation coordinate with appropriate commands if notifications or compliance agreements with regulatory agencies are required as part of the POA&M?		*Response*
	M-04130-00000	MCO 4200.9(b), MCO Appendix C	
Question:	Does the installation develop and submit a POA&M using the POA&M module in ACE?		*Response*

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The page below shows Policy Management questions, as indicated by the 'EPM-POL' code in the upper right corner, under the 'Program' listing. Notice that various Marine Corps Orders (MCOs) are referenced as Regulations for each question.

Master Checklist - CA SBA 04A /CA 04A/MCO 03A /FED 03A

Effective Date: 07/01/1998

Program	Sequence#	Regulations

EPM-POL

M-01000-00000 MCO P5090.2A Chapter 1

Question: GENERAL POLICIES AND RESPONSIBILITIES — *Response*

M-01003-00000 MCO 1101.3

Question: Has the installation obtained copies of its respective state and local regulations to determine if the installation is subject to requirements which go beyond the Federal laws and regulations outlined within MCO P5090.2A? — *Response*

M-01007-00000 MCO 1101.3

Question: Does the installation ensure that Commanders of deployed units are aware of changing requirements as the units deploy to locations different from their home installation? — *Response*

M-01040-00000 MCO 1300, MCO 2226, MCO 2302.8

Question: Has the Commanding General/Commanding Officer (CG/CO) of the installation published a single environmental compliance and protection standard operating procedures (ECPSOP) document? — *Response*

Note: Separate commands which are not co-signatories on an installation ECPSOP will also publish an ECPSOP. A single ECPSOP ensures continuity of effort and prevents conflicts in policies between various environmental media programs. The local implementation of the policies and requirements contained in this chapter are required to appear in the ECPSOP. The ECPSOP will be prepared in a manner complementary to, but not repetitive of, MCO P5090.2A.

Note: Commander Marine Forces Reserve (COMMARFORRES), will publish an ECPSOP for all MARFORRES installations.

M-02000-00000 MCO P5090.2A Chapter 2

Question: ENVIRONMENTAL PROGRAM MANAGEMENT — *Response*

M-02015-00000 MCO 2103.3

Question: Does the installation ensure that environmental impacts of major Federal actions with the potential to significantly affect the quality of the human environment are built into the decision-making process? — *Response*

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The page below shows Policy Management questions, as indicated by the 'EPM-POL' code in the upper right corner, under the 'Program' listing. Notice that various Marine Corps Orders (MCOs) are referenced as Regulations for each question.

Master Checklist - CA SBA 04A /CA 04A/MCO 03A /FED 03A

Effective Date: 07/01/1998

Program	Sequence#	Regulations	
EPM-TNG			
	M-05000-00000	MCO P5090.2A Chapter 5	
Question:	ENVIRONMENTAL TRAINING AND EDUCATION		Response
	M-05010-00000	MCO P5090.2A 5200	
Question:	ENVIRONMENTAL TRAINING POLICY		Response
	M-05050-00000	MCO 5302.7	
Question:	Does the installation use the results of ECEs and installation inspections to refine training needs, to guide priorities for environmental training efforts, and to evaluate training effectiveness?		Response
	M-05060-00000	MCO 5302.9	
Question:	Does the installation plan, program, budget, execute, and track costs associated with the environmental training program in the same manner and to the same degree that other environmental projects and training programs are administered?		Response
	M-05100-00000	MCO P5090.2A 5201	
Question:	COMPREHENSIVE ENVIRONMENTAL TRAINING AND EDUCATION PROGRAM (CETEP) IMPLEMENTATION		Response
	M-05120-00000	MCO P5090.2A 5201.2	
Question:	Required CETEP Components. Note: Each installation CETEP must appropriately and adequately address the program components listed and described in questions EPM-TNG F-05130-00000 through F-05180-00000.		Response
	M-05130-00000	MCO P5090.2A 5201.2(a)	
Question:	CETEP Environmental General Awareness Component		Response
	M-05140-00000	MCO 5201.2(a)	
Question:	Does the installation's CETEP include an environmental general awareness component?		Response

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Appendix B: Evaluation of Parametric Assumption Tests for Research Question 2

McClave et al. (2001) described steps for creating linear regression model from a sample data set, in the form of equation 2, illustrated below.

$$y = \beta_0 + \beta_1 x + \varepsilon \qquad (2)$$

where:
- y = dependent or response variable
- x = independent or predictor variable
- β_0 = y-intercept of the line
- β_1 = slope of the line; amount of increase or decrease in the deterministic component of y for every 1-unit increase in x
- ε = random error, unexplainable variation between variables of interest in model

Recall that for this research question, in each case a respective Management score was the independent variable, and the Total Compliance score was the dependent variable.

In order to create a valid model, certain parametric assumptions concerning the random component ε of the probabilistic model must be fulfilled which are listed below (McClave et al., 2001: 473):

Assumption 1: The mean of the probability distribution of ε is 0. This was evaluated by plotting the residuals from the experimental y values as compared to the least squares fit line.

Assumption 2: The variance of the probability distribution of ε is constant for all settings of the independent variable x. To evaluate this assumption, the residuals associated with the sample data and regression line was plotted and compared to a mean residual value to find if ε is constant for all values of x.

Assumption 3: The probability distribution of ε is normal. This was evaluated by performing a Goodness of Fit test using the Shapiro-Wilk W test statistic. The Shapiro-Wilk test states that the null hypothesis is that ε is distributed normally, and the alternative hypothesis is that ε is not distributed normally. P-values associated with the test were compared against an alpha value of 0.05 to determine whether to accept or reject the null hypothesis that the probability distribution of ε was normal.

Assumption 4: The values of ε associated with any two observed values of y are independent. In other words, the value of ε associated with one value of y has no effect on the values of associated with other y values. To evaluate this assumption, the ε values were plotted against y values to check that there was no increasing or decreasing trend associated with the values of ε.

For each case, the sample data was entered into JMP statistical software. JMP calculated the residuals associated with each case, and the four assumptions were evaluated for each case; the results are summarized in Table 13.

Table 13: Parametric Assumption Test Results. In each case, the third assumption was not met, which indicated that a parametric approach using linear regression could not be used to answer the second research question.

	Assumption 1	Assumption 2	Assumption 3	Assumption 4
Total Management vs. Total Compliance	met	met	not met	met
Audit Management vs. Total Compliance	met	met	not met	met
Policy Management vs. Total Compliance	met	met	not met	met
Training Management vs. Total Compliance	met	met	not met	met

In each case, the first, second, and fourth assumptions were met, as the residuals associated with the random error conformed to the requirements of the assumptions. However, in each case, the p-values associated with the Shapiro-Wilks test for goodness of fit were less than 0.05, which indicated that there was sufficient evidence to reject the null hypothesis that ε was distributed normally. Since the sample data did not meet the assumptions required for a parametric approach using linear regression, nonparametric regression methods were then applied.

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14. ABSTRACT
Environmental compliance on military is challenging for a number of reasons, including the complexity of regulations, and the variety of operations which impact the environment. At times, public concerns and penalties stemming from environmental issues has infringed upon the United States Marine Corps' (USMC) ability to use all installation resources without restriction. This thesis examines which facets of environmental management are closely associated with high levels of compliance. Five variables of interest: Total Compliance, Total Management, Audit Management, Policy Management, and Training Management were isolated from 1998-2004 USMC environmental audit data, and subjected to statistical analysis. Through the examination of four specific research questions, it was found that a) the Marine Corps has been meeting environmental compliance and management standards despite limited resources, b) in all areas, high Management scores were associated with high Total Compliance scores, c) the level of Management in all areas has improved over time, and d) difficulties with non compliance are most often associated with a lack of Resources.

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